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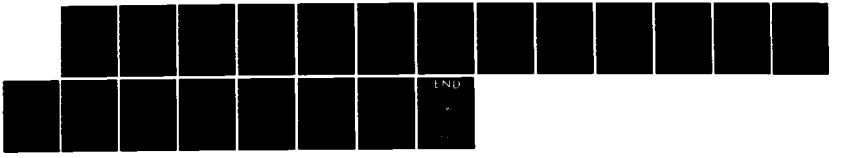

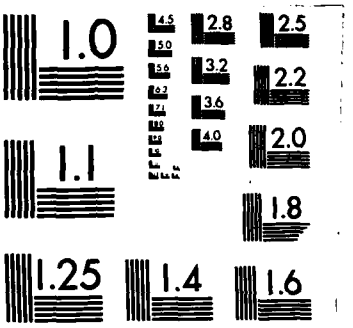

AN EVALUATION OF A COMPUTER BASED MEDICAL DIAGNOSTIC/INFORMATION SYSTEM FOR NUCLEAR SUBMARINES[1]

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Abstract

A computer based medical diagnostic/information system (MEDIC) which will assist the corpsman in diagnosis and treatment of illness is being evaluated at Navy Hospitals and aboard submarines. The system, an adaptation of one developed by deDombal for use by physicians at the University of Leeds, England, has been successful in the diagnosis of abdominal pain. The diagnostic program, based upon a Bayesian algorithm, uses only information obtained from patient history and physical examination. Corpsmen are given special training in the collection of this data. The evaluation compares the accuracy of the diagnostic information system, when used by trained corpsmen, with the unaided diagnoses of Navy emergency room corpsmen and physicians. Use of this system can significantly reduce risk to the patient as well as unnecessary and costly medical evacuations. An expanded version will provide diagnosis, treatment guides and prognosis.

The provision of adequate medical service in isolated areas presents a challenge even to the most experienced medical practitioner. Such problems are magnified for the Navy Hospital Corpsman who represents the only source of medical care aboard nuclear submarines. While Corpsmen receive intensive classroom medical training specifically designed to prepare them for their task, they must be considered to be paramedics with limited clinical experience. Because he has few medical facilities

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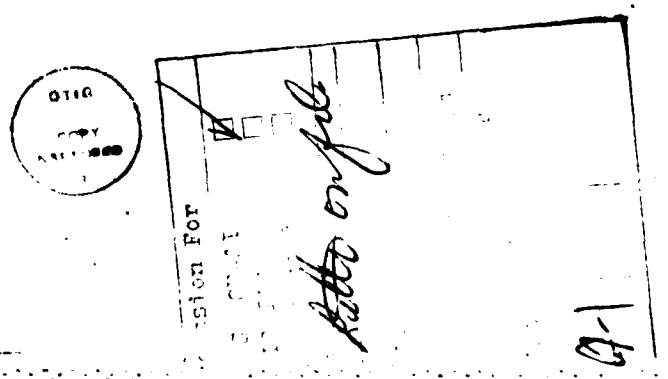
available to him and cannot communicate with other installations, the difficulty of the corpsman's task is increased. Such commonly accepted diagnostic tools as x-ray and EKG are not available. Submarine crews receive intensive medical screening and are a comparatively young segment of the population. The incidence of serious illness is low. However, the occurrence of a single medical casualty which might have been avoided is not acceptable. When life-threatening illness occurs, the corpsman may request that the patient be evacuated from the submarine to a shore based medical facility. Such evacuation can result in termination of the mission. Not only is evacuation costly in terms of military objectives and monetary involvement, but the transfer of the patient, who must be removed by helicopter, may result in the loss of life, a condition which it was intended to obviate.

As a solution to these medical problems, Ryack and Moeller (1976) have suggested the development of an interactive computer based medical diagnostic/information system (MEDIC) which would serve as a surrogate medical consultant. When fully operable. this patient management system would provide the corpsman with diagnostic and treatment guides. Computerized diagnostic tools, patient monitoring devices, and refresher training programs could be developed as adjuncts to the system (Ryack, Henderson, and Moeller, 1979). A conceptual model of such a system (Rogers, Ryack, and Moeller, 1979) is shown in Figure 1.

Since the most commonly reported illnesses aboard nuclear submarines are those related to abdominal pain (Hester, 1971) and since these patients are those most commonly considered for evacuation (Ryack, et al, 1976) the



development of MEDIC was initiated in this area. From our survey of the literature (Rogers, et al, 1979) an abdominal pain program developed by deDombal (1973) appeared to be most readily adaptable to our requirements. The program could be implemented on a mini-computer, diagnosed without the use of laboratory tests, and was purported to have a diagnostic accuracy of 91% when used by surgeons (deDombal, 1972, 1973). With the cooperation of Dr. deDombal and the University of Leeds, this program was adapted for use on a NOVA 1220 computer and subjected to preliminary evaluations. Subsequently, it was modified for use on a TEKTRONIX 4051 desk-top computer (Henderson, et al, 1978) which is aboard nuclear submarines and is accessible to the corpsman.

The program utilizes a Bayesian model to generate disease probabilities in eight areas: Appendicitis (APPEND), Diverticulitis (DIVERT), Perforated Duodenal Ulcer (PERFDU), Cholecystitis (CHOLE), Small Bowel Obstruction (SBO), Renal Colic (R.COLIC), Non-specific Abdominal Pain (NSAP), and Dyspepsia (DYSPP). Included in Non-specific Abdominal Pain are diseases which are not considered to require evacuation such as Gastroenteritis, Urinary Track Infection, Cystitis, and Mesenteric Adenitis. The structure of the program is summarized in Figure 2. At the option of the corpsman, the program will generate data sheets (Figures 3 and 4) which are used to obtain the history and physical information required to make a diagnosis. After each item has been entered into the computer a summary of the data entered and the diagnostic probabilities for each disease category are displayed for the corpsman (Figure 5). A more detailed description of the operation of this program is given by Henderson, et al, 1978.

Although the program has been successfuly used by physicians at Leeds (deDombal, 1972, 1973), there are differences between this application

and that of the MEDIC system which is intended for use in an isolated non-hospital environment. The Navy corpsman differs from physicians in training and clinical experience, and the data base from which the diagnoses is derived was developed from a population with characteristics different from our population.

The present paper describes two studies which were undertaken to determine whether valid diagnoses could be obtained from the abdominal pain diagnostic program by Navy corpsmen and to determine what modifications might be needed to increase the validity of the program.

Experiment 1

The purpose of the first study was to evaluate the relative diagnostic accuracy of the computer when used by corpsmen in the clinical setting of a Navy Hospital. It was conducted in the emergency room at the Balboa Naval Hospital, San Diego, California.

Procedure

Method

Corpsmen at the Independent Duty Technicians School (IDT), Health Sciences Education and Training Command, San Diego, and Emergency Room Physicians participated in the study. IDT students were in the last phase of training during which they rotate for two weeks through the emergency room of the Naval Hospital. Prior to their rotation, these students were given approximately eight hours of instruction in the use of the diagnostic system. They were instructed on how to record and elicit the information

required for completion of the data sheets and in the use of the computer. The level of training of participating physicians ranged from intern to attending physician.

Patients with abdominal pain previously undiagnosed and lasting less than seven days were included in the study. When possible, the IDT student was the first to evaluate the patient. Either during or after the examination, he completed the data sheet on the patient. When final disposition of the patient had been made, the data sheet information was entered into the computer. Determination of final diagnosis in admitted patients was made from discharge diagnosis, pathological diagnosis, and/or definitive laboratory tests. For those patients not admitted, with the exception of those cases where diagnosis was made by laboratory studies, radiographically, etc., passage of a 12 week period without a subsequent visit to the Naval Hospital established a diagnosis of "Non-specific Abdominal Pain".

After final diagnosis had been determined, diagnostic accuracy of the computer-aided corpsman was established as follows: The computer-generated diagnosis was taken as any probability exceeding 50%. When no disease probability exceeded 50%, a diagnosis of "Non-specific Abdominal Pain" was recorded. These computer-generated diagnoses were compared to the final diagnoses.

Results

One hundred eighty-six cases of abdominal pain were obtained in the period between March 1978 and June 1979. Of these, 53 cases were omitted from the evaluation either because the diagnosis had not been confirmed,

data was missing, or the final diagnosis was inappropriate for the evaluation. The overall diagnostic accuracy obtained was 73.7% for the physician and 61.6% for the computer. Staniland (1972) reports that 30-40% of cases can be expected to be misjudged on presentation at the hospital. The obtained accuracy of both the computer and physician fall within this 60-70% expected error range. The relative diagnostic accuracy of the physician and computer was dependent on disease area and is summarized in Table 1. The computer's accuracy exceeded that of the physician only for dyspepsia. No cases were obtained in two of the disease areas evaluated by the computer program, diverticulitis and perforated duodenal ulcer.

Table 2 shows the disposition of the 133 cases based upon the diagnostic accuracies of the computer and physicians. Patient management based on computer diagnosis approximates that of the physician. Physicians would have appropriately held, managed, and evacuated 12.4%, 4.7%, and 7.7% more cases respectively than the computer.

Experiment 2

The purpose of this study was to evaluate the unaided diagnostic accuracy of the corpsman. It was conducted in the clinical setting of the Emergency Room of the Boone Clinic, Little Creek, Virginia.

Procedure

Method

Students at the Independent Duty Technicians School (IDT), Health Sciences and Education Training Command, Portsmouth, Virginia, and Emergency Room Physicians participated in the study. The composition and training of the IDT students was similar to those at San Diego with the exception that they spent only one week on their rotation.[1] The students were not instructed in the use of the computer-diagnostic system and did not use the computer data sheets. Prior to their rotation, they were familiarized with the study. Participating physicians were Physicians Assistants, Interns, and General Duty Medical Officers.

The patient population was similar to that used in San Diego. The IDT student was the first to see the patient. Subsequent to his examination, and without consulting with a physician, he recorded his diagnosis on an examination record form. The attending physician recorded his own diagnosis on the same form. The procedure for obtaining the final diagnosis was similar to that for Experiment 1 with the following exceptions: At the end of an eight week period, all patients who had not been admitted or returned for a subsequent visit were followed up with telephone contact to determine whether there had been any further difficulties. Diagnostic accuracy of the corpsman was evaluated by comparing his diagnosis to the final diagnosis.

Results

Seventy-five cases of abdominal pain were obtained during the fifteen week period between January 1979 and May 1979. Thirty-three cases were omitted from the analysis because of the absence of a confirmed diagnosis,

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[1] A second week was spent in Military Sick Call which provides similar experience.

missing data, or the presence of a clinical problem inappropriate to the study.

No cases were obtained for Small Bowel Obstruction, Cholecystitis, Diverticulitis and Perforated Duodenal Ulcer. This is not surprising since the sample of cases in this study is relatively small and these diseases have a low probability of occurance. For purposes of comparison with computer diagnostic performance, diagnoses of appendicitis, dyspepsia and renal colic were combined into a single "Specific" category. Since the computer was not used in this study, the data from Balboa was used for the comparisons made in Table 3. The corpsman diagnosed "Non-specific" diseases better than the computer; the computer was more accurate than the corpsman for the "Specific" diseases.

Discussion

deDombal (1975) has reported diagnostic accuracies for the computer between 81% and 91%; the overall diagnostic accuracy we obtained was only 61%. This difference may be attributable to characteristics of the data base, experience of the corpsmen, and training variables. The population from which the data base was developed differs from that to which it was applied. The data base was intended for use with the general population of patients which might present with abdominal pain at Leeds. The data from which the data base was developed placed no restrictions upon age of the patient and was derived primarily from patients who had been previously seen by a physician and were referred to a hospital. Our application population was restricted with an age range between 14 and 60 years[1] and

[1]The normal age range for submarine population would be 17-60.

had not previously been seen by a physician. A data base more appropriate for this population is presently under development.

Although Navy Corpsmen have intensive classroom training, the program provides for relatively little clinical experience before going aboard a submarine. Studies currently being conducted in our laboratory indicate that there may not be sufficient transfer from the classroom to the clinic to enable them to correctly diagnose the more serious evacuable diseases. While corpsmen at San Diego were given special training in the elicitation of history and physical symptoms required for the use of the computer, in the absence of clinical experience, the data were probably not adequately elicited and recorded. The paramedics and physicians in deDombal's studies had either extensive experience in the use of the system or extensive clinical experience. Further evaluations are being undertaken in these areas.

As shown by Table 3, the computer's diagnosis was superior to the corpsman's for the "Specific" diseases but not for the "Non-specific". Since most of the corpsman at this point in training do not have extensive clinical experience, their level of performance was surprising. One possible explanation is that contrary to our experimental design, the corpsman did not diagnose independently of the physician. However, the physician's diagnostic accuracy of 61% in contrast to the corpsman's accuracy of 29% for the "Specific" diseases does not support this hypothesis. The more probable explanation for this difference may be in the relative probability of occurance of diseases. If the corpsmen in this study had made no other diagnosis than "Non-specific" pain, they would have been correct 83% of the time. This hypothesis is strongly supported by the

overall diagnostic accuracy of 83.3% (Table 3) obtained in this study. The high level of diagnostic accuracy may have been in part a function of probability matching rather than of diagnostic skill. We are presently investigating this hypothesis.

Our data suggests that the computer-based diagnostic system, developed for use by physicians in a hospital setting, can be adapted for use by paramedics in an isolated environment. The effectiveness of the computer in diagnosing evacuable diseases is encouraging and can result in the reduction of both the loss of a patient and serious complication. It is not likely that the present tendency of the computer program to place some non-evacuable patients in other categories would result in unnecessary evacuations. Unless the situation is acute, patients on board a submarine are normally observed for a period fo time before being evacuated. As the illness progressed, the correct diagnosis would become more obvious and evacuation would not occur. We are, however, concerned with this problem and are evaluating methods of correcting it.

Disclaimer

The opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the Navy Department at large.

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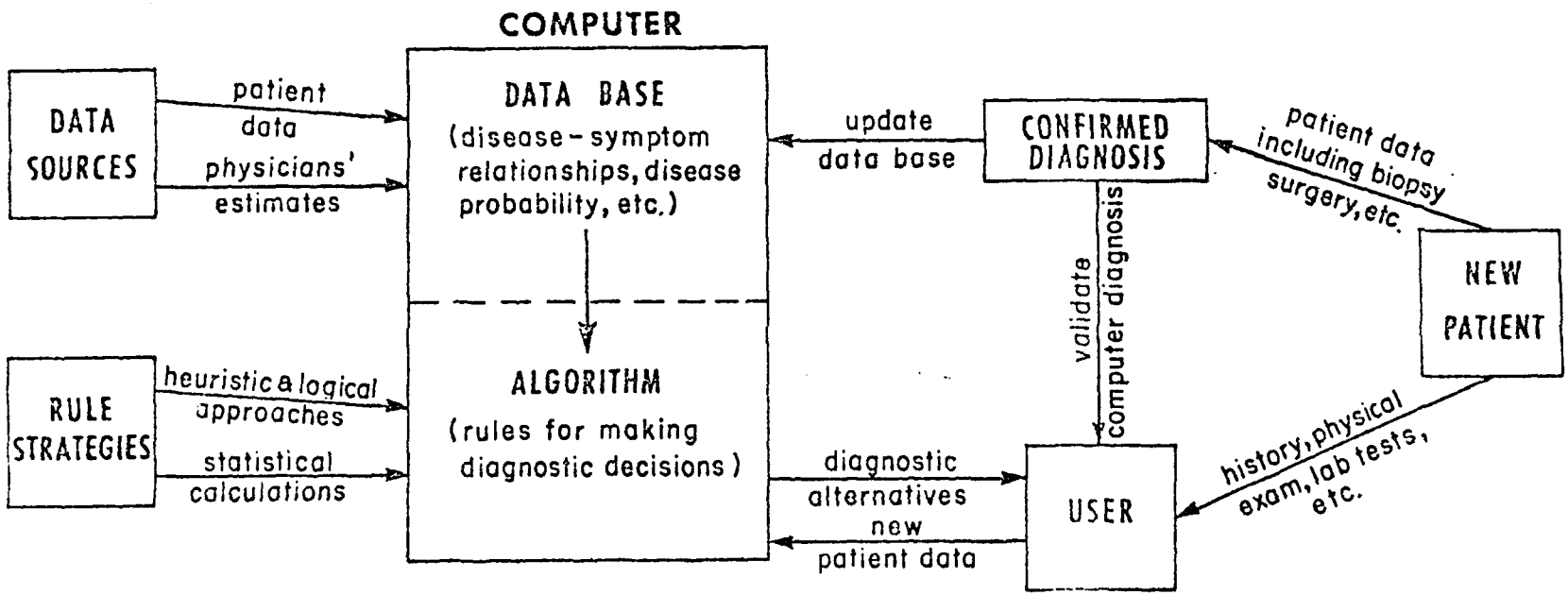


FIG. 1 Conceptual Model of the MEDIC System

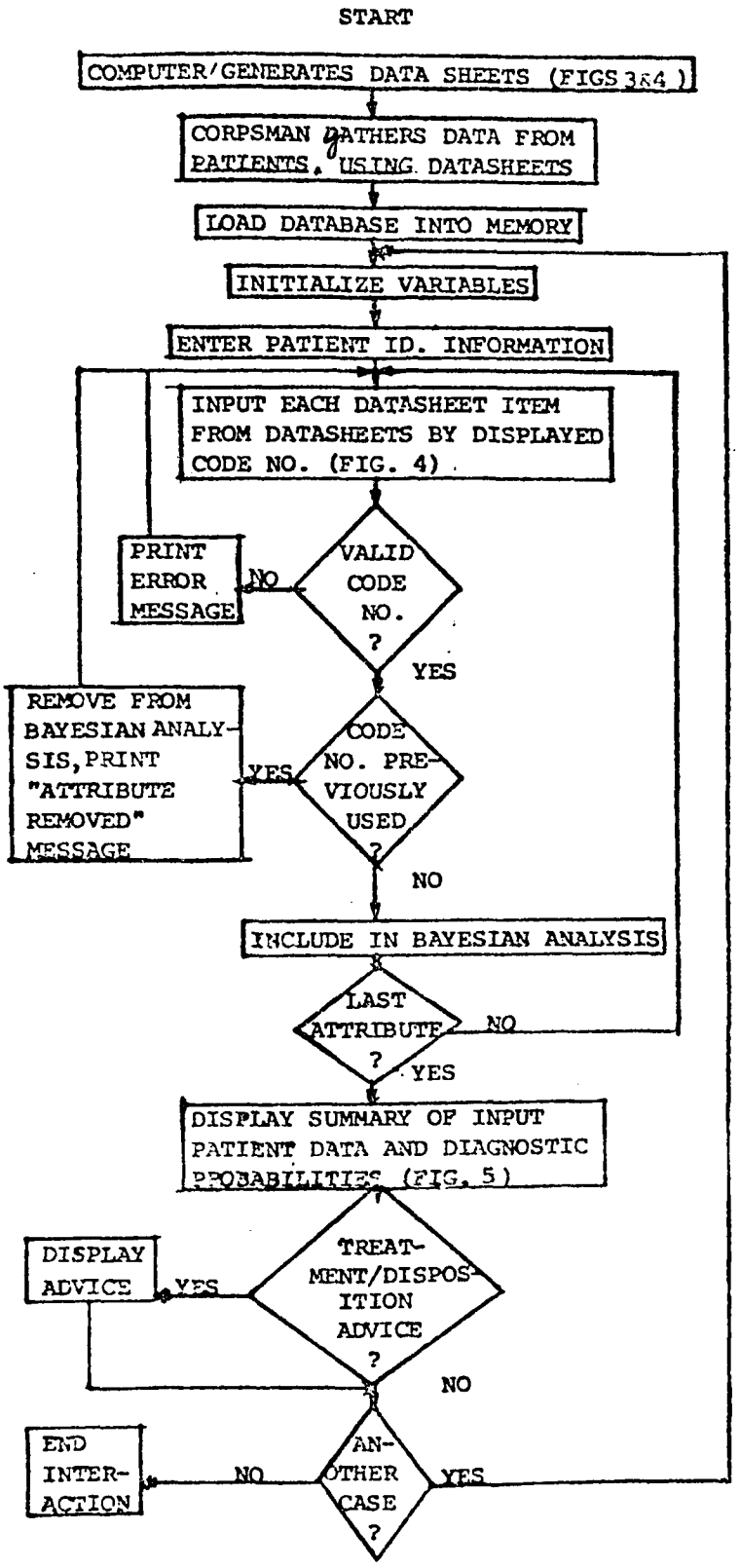


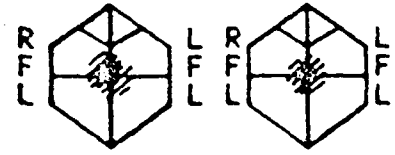
FIG. 2 Flow Chart of the Abdominal Pain Program

DATASHEET: Acute Abdominal Pain---
PAGE 1- History

Patient SSN:
Time/Date: 1600 78 JUN 07
Age: 18

PAIN

SITE:



TYPE AT ONSET: INTERMITTENT/STEADY/COLICKY

TYPE AT PRESENT: INTERMITTENT/STEADY/COLICKY

SEVERITY: MODERATE/SEVERE

PROGRESS: BETTER/ SAME/WORSE

DURATION: <12h/12-24h/24-48h/48+h

AGGRAVATING FACTORS: MOVEMENT/COUGH/BREATHING/FOOD/OTHER/NONE

RELIEVING FACTORS: LYING STILL/VOMITING/ANTACIDS/FOOD/OTHER/NONE

OTHER SYMPTOMS NAUSEA: YES/NO VOMITING: YES/NO

APPETITE: DECREASED/NORMAL JAUNDICE: YES/NO

BOWELS: NORMAL/CONSTIPATED/DIARRHEA/BLOOD IN STOOL/MUCUS IN STOOL

URINATION: NORMAL/FREQUENCY/PAINFUL/DARK URINE/BLOOD IN URINE

PAST HISTORY PREVIOUS INDIGESTION: YES/NO

PREVIOUS SIMILAR PAIN: YES/NO PREVIOUS SURGERY: YES/NO

PREVIOUS ILLNESSES: YES/NO (Comment on pertinents on back)

TAKING MEDICATIONS: YES/NO (Physical Exam on next sheet)

FIG. 3 Datasheet for Taking History

DATASHEET: Acute Abdominal Pain---
PAGE 2-Physical Exam

Patient SSN:
Time/Date: 1600 - 78 JUN 07

VITAL SIGNS TEMP- 99.8 PULSE- 100 BP- 80/120 RESP- 18

GENERAL EXAM

MOOD: NORMAL/DISTRESSED/(ANXIOUS)

COLOR: NORMAL/(PALE)/FLUSHED/JAUNDICED/CYANOTIC

ABDOMINAL EXAM

INSPECTION: (NORMAL)/VISIBLE PERISTALSIS/DECREASED RESPIRATORY MOVEMENT

SCARS: YES/(NO) DISTENTION: (YES)/NO

REBOUND: (YES)/NO GUARDING: (YES)/NO

RIGIDITY: YES/(NO) MASSES: YES/(NO)

MURPHY'S SIGN: PRESENT/(ABSENT)

BOWEL SOUNDS: NORMAL/DECREASED OR ABSENT/(HYPERACTIVE)

RECTAL EXAM: (NORMAL)/MASS FELT/GUAIAC TEST FOR BLOOD POSITIVE

TENDERNESS- ON LEFT/ON RIGHT/GENERAL

TENDERNESS

FIG. 4 Datasheet for Physical Examination

PATIENT SSN: 000-00-0000

TIME/DATE ENTERED: 930/150CT79

SYMPTOMS

MALE	NO PREV. SIM. PAIN
AGE 10-19	NO PREV. ABD. SURG.
ONSET CENTRAL	NOT TAKING MEDS
PAIN NOW CENTRAL	MOOD ANXIOUS
MOVEMENT AGGRAVATES	COLOR PALE
COUGHING AGGRAVATES	ABD MOVEMENT NORMAL
LYING STILL RELIEVES	NO ABD SCARS PRESENT
ANTACIDS RELIEVE	ABD DISTENDED
PAIN NOW WORSE	GENERAL TENDERNESS
DURATION <12 HRS	REBOUND PRESENT
PAIN COLICKY	GUARDING PRESENT
PAIN IS MODERATE	NO RIGIDITY
NO NAUSEA	NO ABD MASSES
NO VOMITING	MURPHY'S NEGATIVE
APPETITE DECREASED	HYPER. BOWEL SOUNDS
NO PREV. INDIGESTION	RECTAL - NORMAL
NO JAUNDICE	
BOWELS NORMAL	
DYSURIA PRESENT	

APPEND	DIVERT	PERFDU	NONSAP	CHOLE	SMBOBS	RCOLIC	DYSP
69.61	0.00	0.00	30.37	0.00	0.00	0.00	0.01

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FIG.5 Summary of data input to computer. Diagnostic probabilities are in percent. The computer diagnosis of appendicitis was verified at the time of surgery.

Table 1

Relative Diagnostic Accuracy[1] of Physician and Computer by Disease[2]

In San Diego

Disease	Computer	Physician
Non-Specific Pain	62.0	74.6
Dyspepsia	55.0	30.0
Renal Cholic	25.0	100.0
Small Bowel Obstruction	25.0	75.0
Cholistitis	57.1	71.4
Appendicitis	77.8	100.0

[1]Percent Correct, N=133

[2]No Cases of Diverticulitis or Perforated Duodenal Ulcer were obtained

Table 2

Patient Management Based Upon Computer and Physician Diagnostic Accuracy[1]

Disposition	Computer	Physician
Appropriately Managed	76.7	89.1
Inappropriately Evacuated	18.0	10.3
Inappropriately Held	5.3	0.6

[1]Values are in percent, N=133.

Table 3

Diagnostic Accuracy[1] of Computer and Corpsman

for "Specific" and "Non-Specific" Diseases

Classification	Corpsman (Portsmouth)[2]	Computer (San Diego)[3]
Non-Specific	94.3	62.0
Specific	28.6	61.3
Total	83.3	61.7

[1]Percent Correct

[2]N= 133

[3]N= 43

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