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UNCLASSIFIED 448-103-05/01 USCG-D-40-80 NL

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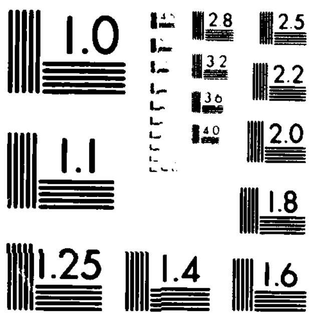

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NATIONAL BUREAU OF STANDARDS 1963 A

REPORT NO. CG-D-40-80

A STUDY TO DETERMINE THE EVOLUTION OF ADVANCES IN MEDICAL TECHNOLOGY EXPECTED IN THE NEXT 25 YEARS AND POSSIBLE IMPACTS ON COAST GUARD OPERATIONS AND SUPPORT PROGRAMS

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115

May 1980

FINAL REPORT

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United States Coast Guard
Washington, DC 20590

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16. Abstract

This report reviews a broad range of potential medical developments which might occur over the next 25 years, identifies those which have particular significance to the Coast Guard, and suggests potential effects on the Coast Guard's ability to perform its current and anticipated medical missions. Specific areas are emphasized, including emergency medicine, remote transmission of health data, computer applications, and mobile health units. Within these areas, new technologies were identified as diagnostic, preventive, therapeutic or rehabilitative, supportive, or "organizational," and they were further specified as techniques, drugs, equipment, or procedures.

Significant advances are anticipated in "nonmedical" technologies which interface with the delivery of medical care, including remote monitoring and telecommunications (teleconsultation and transmission of medical records), advanced medical record-keeping systems (which can be used to anticipate problems of personnel both within the Coast Guard and in the population they serve), and improved technologies in the delivery vehicles. Advances in emergency medicine which will stabilize patients and initiate treatment are identified (e.g., spray-on burn "bandage" and artificial blood).

Future missions and demand for medical services are forecast; specific implications and recommendations are suggested.

17. Key Words FUTURE MEDICINE, MOBILE HEALTH CARE, EMERGENCY MEDICINE, COMPUTER APPLICATIONS MEDICAL, HEALTH DATA TRANSMISSION	18. Distribution Statement Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

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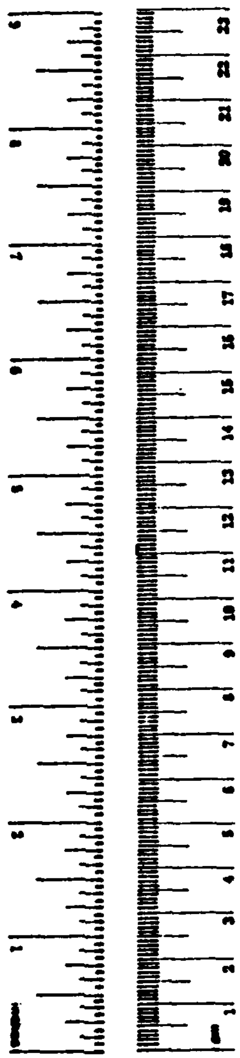
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

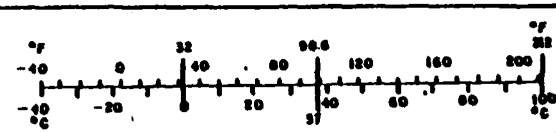
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



CONTENTS

CONTENTS (CONT.)

1. INTRODUCTION

Revolutionary advances will occur in medical technology and in the organization and practice of medicine in the next 25 years. These advances not only will affect the rates of morbidity and mortality through earlier detection of disease and more effective therapy, but will also improve the general level of health and vigor through improved treatment of chronic diseases such as arthritis. New delivery systems and trauma procedures will improve survival rates in accidents. These developments, largely based on new technology and new knowledge of the causes of disease, will be matched by changes of equal scope in the organization and administration of medicine; developments in this domain include, for example, increased use of paramedics, national health insurance, and maximum allowable cost legislation. All of these developments are relevant to the Coast Guard, not only from the standpoint of delivery of health care to personnel, but also in the execution of its missions.

The central objective of this study was to review a broad range of potential medical developments--including technological, biomedical, institutional, and other factors--which might occur over the next 25 years, to identify those which had most significance to the Coast Guard, and to study the potential effects on the Coast Guard resulting from the realization of these developments.

As this report makes clear, the medical developments which seem possible over the next 25 years are exciting, and in many cases revolutionary. Many of these developments will be very important to the Coast Guard because they will improve the Coast Guard's capability to perform existing or new missions; others will have a large impact on medicine in general, but small effect on the Coast Guard. In this latter category are developments in the realm of diagnostic or improved therapy for diseases rarely of concern to the Coast Guard. By way of illustration, a new test developed at Washington University School of Medicine measures the release of an enzyme (creatine phosphokinase) from damaged heart muscle to determine whether infarction damage is extensive and increasing in size. Another diagnostic test measures protein myglobin in the urine by radioimmuno diffusion: higher levels of urinary myglobin are associated with damage to the heart muscle. In addition, certain radioactive minerals tend to concentrate in normal heart tissue only; when viewed from outside the body with a scintillation camera, damaged heart muscle appears as

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Members of The Futures Group staff who contributed to this study are Theodore J. Gordon, Louise Mason, and Harry Truitt. Consultant contributions were made by Dr. Herbert Gerjuoy, Dr. Gordon Hatcher, and Dr. J. Frank. The study team also wishes to acknowledge the contributions and guidance provided by Mr. William Stover, the study's project monitor at the Coast Guard.

a "cold spot." Despite the importance of these heart disease diagnostic tools, the impact of such developments on the Coast Guard might be relatively minor. While they might reduce mortality due to heart disease in the population at large, for the Coast Guard these techniques would simply represent extensions of current practice. Thus, we are concerned in this study with identifying not only important medical developments but in particular the subset of developments likely to have a most profound effect on the Coast Guard.

We found that future medical developments could have important effects on the Coast Guard in several ways, including

- improvements in emergency medicine.
- remote transmission of health data.
- new computer applications, particularly record-keeping.
- availability of new mobile health care laboratories for providing disaster relief.
- changes in the numbers and training of USCG medical personnel.
- new medical screening procedures for USCG personnel, and concomitant changes in personnel performance, mix, and assignment practices.
- changes in administration of medical services within the USCG.

All of these dimensions are addressed in some detail in this report. This report has 5 major sections following this introduction:

- The balance of this chapter describes the study design and methodology employed
- Chapters 2-5 deal with 4 specific areas of change that will be important to the Coast Guard. These are
  - emergency medicine
  - remote transmission of health data
  - computer applications
  - mobile health units.

These 4 topics were identified from among 150 or more as being crucial to Coast Guard interests.

- Chapters 6 and 7 deal with the effects of new developments on existing and new Coast Guard missions. The question addressed here is, "If the forecasted medical developments were to occur, what difference would they make to the Coast Guard?"

- Chapter 8 summarizes the conclusions of the report and contains recommendations based on this research.

- Appendix A presents a 20-year overview of the future of medicine without particular consideration of the Coast Guard. This chapter is designed to provide a backdrop for the material that follows and deals with the broad panorama of changes which will characterize the advancing frontiers of medicine. This appendix includes consideration of new diagnostic techniques, new therapies, infrastructural changes, the regulatory environment, and similar factors.

- Appendix B describes Trend Impact Analysis, the forecasting tool used in this study.

- Appendix C reports the results of a workshop conducted on August 1, 1979, with medical representatives of the Coast Guard to identify key medical technologies. It also lists the anticipated developments which were considered in this study, together with estimates of their probability as a function of time.

- Appendix D contains the results of a search of The Futures Group's files.

Study Flow

The design of the study is straightforward. As Figure 1-1 illustrates, four tasks were involved. In the first task, prospective medical developments of the next 25 years were identified. In the second task, a subset of developments potentially important to the Coast Guard were selected, and these were studied in more detail and forecasted. In the third task, these developments were assessed in terms of their consequences to the Coast Guard. The Final Report was issued in the last task of the study, describing the substantive findings and recommendations. Each of these tasks had a number of subtasks, as Figure 1-1 illustrates.

The principal objective of Task 1 was to form a list of potentially high-impact medical developments. Several sources were used to derive this list, including a review of the extensive files which currently exist at The Futures Group. The Futures Group currently provides forecasts of developments and key time-series variables and two commercial services to the hospital and pharmaceutical industries; these services are Hospital PROSPECTS® and Pharmaceutical PROSPECTS®. The results of this search are contained in Appendix D; some forecasted developments were identified in this review. While the files of information are quite extensive, they do not contain

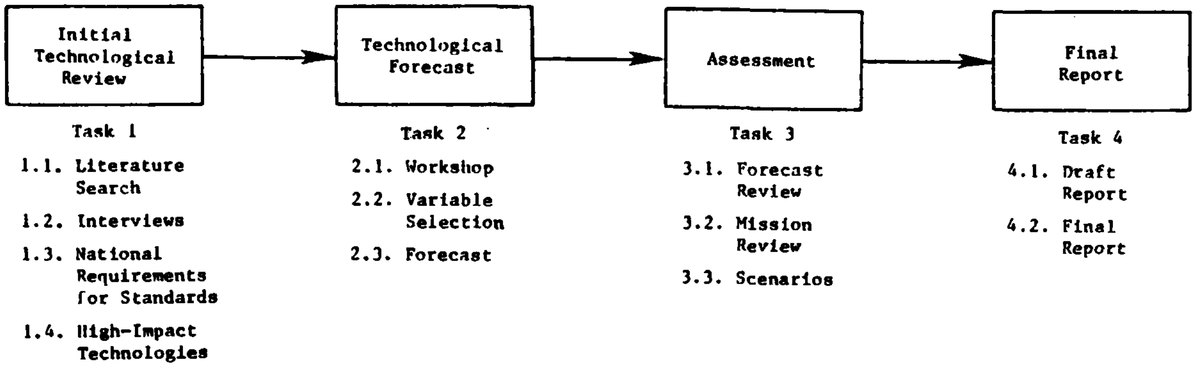


FIGURE 1-1. STUDY FLOW.

extensive information in areas of emergency medicine or remote telemetry of medical data. Therefore, existing data at The Futures Group were augmented through an automated literature data base search. Table 1-1 presents a summary of the on-line data bases that were searched within the SDC and Lockheed files. The results of this search are contained in Appendix E. In all some 1405 literature references were searched. To further augment the initial list of developments, experts in major medical technologies were contacted informally and their suggestions were included in the list.

Throughout these tasks, the future developments were organized into the following major categories:

- Diagnostic technologies
- Preventive technologies
- Supportive technologies
- Organizational technologies
- Therapeutic and rehabilitative technologies

Within these categories subdivisions of: techniques, drugs, equipment and procedures were utilized. The list was screened by the study staff and a subset of some 60 technologies thought to be both plausible and potentially important to the Coast Guard were selected. These technologies are listed in Table 1-2. Each of these 60 technologies was probed to present a brief background, description, and potential applications. An example of this work is shown in Figure 1-2. This figure presents the description of a single item of the set of 60, and the complete set of descriptions is included in Appendix C.

In preparing these descriptions, special attention was given to guidelines for health planning currently being formed and promulgated by the Public Health Service of the Department of Health, Education and Welfare that could affect the delivery of health care in the next decade. For example, current guidelines call for:

- 4 beds per 1000 population (1977 = 4.5)

TABLE 1-1. ON-LINE DATA BASES CONTAINING INFORMATION ON BIOMEDICAL TECHNOLOGIES.

NAME OF DATABASE	DESCRIPTION	SOURCE	FILE SIZE	UPDATE
BIOSIS	Includes contents of Biological Abstracts and BioResearch Index covering the entire life sciences. Literature selected includes original research reports in biological fields, and history and philosophy of the biological and biomedical sciences. Covers approximately 8,000 serial publications as well as books, notes, research communications and symposia.	SDC Lockheed	200,000/yr. covers Jan. 1969 to date	BA: Biweekly 6,000 citations Bio I: Monthly 8,000 citations
EXCERPTA MEDICA	Provides international coverage of periodical articles, books, dissertations, and conference proceedings on human medicine and related disciplines. Covers over 3,500 worldwide biomedical journals.	Lockheed	260,000/yr. covers Jan. 1975 to date	Weekly 5,000 citations
NTIS	Consists of government-sponsored research, development, and engineering reports plus analyses prepared by federal agencies, their contractors or grantees. Multi-disciplinary scope includes biological and medical sciences, chemistry, oceanography, and military sciences.	SDC Lockheed	60,000/yr. covers Jan. 1970 to date	Biweekly 2,300 citations
SCISEARCH	Multidisciplinary index to science and technology literature including biochemistry, biology, cardiology, medicine, and surgery. Covers approximately 2,600 major scientific and technical journals.	Lockheed	504,000/yr. covers Jan. 1974 to date	Monthly 42,000 citations
SSIE	Covers on-going and recently completed research in the biological sciences, earth sciences, and medical sciences--both basic and applied research projects. Research in progress is included from over 1300 funding organizations.	SDC	108,000 projects/ yr. FY1974 to date	Monthly 9,000 records

TABLE 1-2. LIST OF TECHNOLOGIES.

DIAGNOSTIC TECHNOLOGIES

- Ability to transmit medically relevant signals from a patient over long distances.
- Ability to interface a long-distance transmitter with computers for biomedically significant analyses.
- Development of a technique for analyzing constituents of blood without having to take samples from patient.
- Availability of a small electronic sensor to measure various electrolyte levels continually.
- Design of an automated system to test the effectiveness of various antibiotics against microorganisms.
- Availability of a procedure for detecting cardiac muscle destruction.
- Research examining the metabolite patterns of a group of specific disease states.
- Development of a method for producing an image of chemical events deep in the body.
- Development of techniques that show promise in the detection of precancerous lesions of the cervix.
- Availability of methods to identify subclinical or recurrent cancers.
- Availability of more specific measurements of burn severity.

PREVENTIVE TECHNOLOGIES

- Matching of induction medical evaluation parameters of personnel to billet requirements.
- Mass health evaluation procedures discontinued.
- Refinement of health hazard assessment technologies.
- Manipulation of the physical and social environment.
- Psychological factors (morale building) in health maintenance.
- Health education employs behavior modification techniques.
- New control measures for common viral and bacterial diseases.
- Decrease in venereal disease as more women enter service.

TABLE 1-2. (CONT.)

SUPPORTIVE TECHNOLOGIES

- Ongoing real-time updating of all personnel medical records.
- Drugs thar control motivation, emotion.
- Drugs that enhance powers of concentration, memory, learning.
- Automated display of actuarial (frequency) data for diagnoses, etc. of cases with similar symptoms.
- Space technology and automation make feasible prostheses bypassing neural, muscular disabilities.
- Equipment for ongoing noninvasive monitoring of normal biological processes.
- Regimens for life-expectancy prolongation and aging retardation.
- Delaney Amendment modified to consider balance of costs and benefits of foods and drugs.
- Compulsory periodic reexamination and relicensing of physicians, other medical and paramedical personnel.
- Widespread dissemination of biomedical information through elementary schools, mass media, etc.

ORGANIZATIONAL TECHNOLOGIES

- Remote health care via telecommunications.
- Increasing computer applications to a variety of diagnostic activities.
- Floating laboratories and emergency water treatment facilities.
- The use of physician extenders.
- Air-transportable laboratories capable of responding to disasters.
- Medical services to retired persons part of standard retirement package, contingent on suitable lifestyle.
- Large organized health service consumer groups have powerful political influence.
- Emergency medicine recognized as a specialty.
- Legal definition of medical profession changed and broadened to include new lifestyle subspecialities.
- Health and survival differences between U.S. and other countries an important international issue.

TABLE 1-2. (CONT.)

THERAPEUTIC AND REHABILITATIVE TECHNOLOGIES (DRUGS)

- Availability of effective agents to prevent allergic reactions
- Availability of effective anti-viral drugs.
- Availability of oral agent to produce temporary male sterility.
- Availability of a treatment to inhibit betalactamase.
- Availability of synthetic beta-endorphins or endorphin-inducers for analgesia.
- Availability of anti-bacterial vaccines.
- Availability of vaccines against diarrhea.
- Availability of vaccines to prevent juvenile-onset diabetes.
- Availability of oral agents to enhance natural secretion of insulin.
- Availability of prostaglandin-based drugs.

THERAPEUTIC AND REHABILITATIVE TECHNOLOGIES (PROCEDURES)

- Use of easily administered adhesives with angiography to stop severe life-threatening hemorrhage.
- Availability of inexpensive, reliable, implantable insulin and sensor infusion systems.
- Availability of new skin grafting technique for burn treatment.
- Availability of more sophisticated devices to relieve pain.
- Availability of effective safe alternative female contraceptives.
- Availability of site-specific drug delivery systems.
- Availability of islet implantation techniques with five- or ten-year duration.
- Treatment with heat energy to destroy cancer tissues.
- Availability of computer-controlled parenteral fluid dosing system for burn patients.
- Widespread use of reinfusion of cryopreserved bone marrow.

AVAILABILITY OF ANTI-BACTERIAL VACCINES

- Research was largely abandoned in the 1940s when antibiotics were introduced.
- Emergence of resistant bacteria strains has led to new interest: antibiotic therapy may no longer be effective (17 percent of penicillin-treated pneumonia patients die).
- New techniques of purification of bacterial antigens and definitions of immunity in biochemical and cell-physiological terms have further aided this research.
- First such vaccine was introduced in 1978 by Merck: effective against 80 percent of pneumonococci causing pneumonia. Use in splenectomized adults, persons with obstructive airway disease or sickle cell disease.
- Haemophilis influenzae (a major cause of otitis media, meningitis, and other acute life-threatening infections of children) treatment is chloramphenicol (toxic) or ampicillin (increasingly resistant). An H influenzae vaccine was recently tested in Finland during a meningicoccal meningitis outbreak. Effective in older children; no protection for those under 18 months.
- In very young children new approaches may be needed: 1) immunizing during pregnancy to transfer antibodies passively until antibody-forming system is mature, or 2) altering polysaccharide antigens by combining them with more immunogenic carrier antigens.
- Meningococcal polysaccharide vaccine effective against group A and C meningococci is available but not effective in young children. Glycopeptide MDP (muramyl dipeptide) may potentiate vaccines by eliciting better antibody responses.
- Pseudomonas aeruginosa (life-threatening Gram-negative infection) vaccine prevented death in burn patients in India (vaccine given within 72 hours of burns).
- Animal studies of a vaccine to protect against legionnaire's disease suggest immunity can be produced.
- Temple University researchers have purified antigens which can be used in a vaccine against Group B streptococcus bacteria: life-threatening in young infant (causes bacteremia and meningitis). Expectant mothers would be immunized.

FIGURE 1-2. DESCRIPTION OF A SINGLE MEDICAL TECHNOLOGY.

- Hospital occupancy rate at least 80 percent (1977 = 73.6)

- Obstetrical care units functioning at 1500 births per year

- Neonatal intensive-care beds targeted at less than 4 per 1000 births

- Minimum of 20 beds in a pediatric unit

- Occupancy rate for pediatric units should be 65-75 percent

- Cardiac catheterization

    ° minimum of 300 catheterizations per year in adult unit

    ° minimum of 150 catheterizations per year in pediatric unit

    ° there should be no new unit opening in any facility that does not do open-heart surgery

- A radiation unit should serve population of at least 150,000 and treat 300 cancer cases per year

- CAT scanners should be performing 2,500 scans per year

- Resources should be organized to support "self-care dialysis."

Also, HEW currently is developing national criteria to be used by Professional Standards Review Organizations (MDs) in assessing the need for the performance of specific surgical procedures. Criteria for 11 common procedures were released early in 1978.

To select a subset of the 60 developments for more detailed study, a half-day workshop was held with Coast Guard medical personnel. In performing this workshop, the candidate technologies were reviewed in turn, and each was assessed in terms of its overall impact on the Coast Guard. In addition, judgments were provided about the impact of each of the technologies on existing Coast Guard missions. Finally, attendees at the meeting were asked to suggest other developments which had not been included in the initial list. Table 1-3 presents an illustration of the judgments received during this workshop. Appendix C presents a complete recapitulation of the judgments received during the workshop. Table 1-4 presents a list of personnel who attended the workshop.

TABLE 1-3. EXAMPLE OF JUDGMENTS RECEIVED DURING THE WORKSHOP SESSION.

Overall impact on Coast Guard: 0-10 scale

Number of people choosing development as relevant to the indicated mission

Newly suggested ideas by participants

SUPPORTIVE TECHNOLOGIES	IMPACT	MISSIONS: OPERATIONAL							MISSIONS: SUPPORT		
		ELT	IO	MEP	MO/MP	PSS	SAR	CVS	GAK	GAI	GAP
Regimens for life-expectancy prolongation and aging retardation.	3.9	2	2	2	3	2	2	2	3	2	4
Compulsory periodic reexamination and relicensing of physicans, other medical and paramedical personnel.	5.8				1				3		2
Widespread dissemination of biomedical information through elementary schools, mass media, etc.	3.1								3		3
Drugs that enhance powers of concentration, memory, learning.	4.9	1	2	2	2	2	2	2	3	2	4
Delaney Amendment modified to consider balance of costs and benefits of foods and drugs.	3.3								4		2
Drugs that control motivation, emotion.	4.9		1	1	2		1	1	4		4
Space technology and automation make feasible prostheses bypassing neural, muscular disabilities.	4.2			2	1		2				
Automated display of actuarial (frequency) data for diagnoses, etc. of cases with similar symptoms.	4.7								3		1
Equipment for ongoing noninvasive monitoring of normal biological processes.	4.0								3		1
[1] Ongoing real time updating of all personnel medical records.	7.1				1				4	1	4

1 *Federal mandate: Management Information System will be required in five years.*

TABLE 1-4. PERSONNEL CONTRIBUTING TO THE WORKSHOP.

1. Captain James A. Esposito
2. Commander James F. McCahill
3. Commander Robert E. Perrow
4. Mr. Steve Tuller
5. Captain J. H. Hensley
6. Captain Philip G. Lawrence
7. Lieutenant D. Terry Graviss
8. Chief Warrant Officer Louis P. Nanni
9. Captain Pietrina Siciliano
10. Lieutenant Commander Al Steinman
11. Mr. William Stover
12. Mr. Theodore Gordon
13. Dr. Gordon Hatcher
14. Mr. Harry Truitt
15. Dr. J. M. Frank
16. Dr. Herbert Gerjuoy

The workshop was conducted using a CONSENSOR®. A Consensor is a voting device useful in group meetings. Participants in such meetings use small terminals that can accept two inputs. The first is a numberical answer to a question posed by the moderator. The second is an estimate by each participant of his confidence in his judgment. A small microprocessor computer combines these inputs--weighting each vote according to indicated confidence. The range of opinions of the group is then displayed on a monitor in the form of a bar graph. All judgments are anonymous. The degree of consensus or disagreement can be observed quickly on the monitor display and discussion can be directed toward resolution of differences of opinion. If consensus cannot be achieved, at least reasons for disagreement are crystalized.

The judgments contributed at the workshop indicated that four development areas were likely to be of great significance to the Coast Guard:

- Emergency medicine

- Remote transmission of health data

- Computer applications

- Mobile health units.

In-depth studies were conducted on these four topics; these studies form major chapters within this report. Within each study we analyzed recent developments and impacts of these developments important to the Coast Guard.

These in-depth studies and the earlier forecasts of medical developments were reviewed systematically against existing and potential future Coast Guard missions to determine how these missions might be affected. The results of these impact studies are contained in Chapter 7 of this report. This analysis began with a forecast of Coast Guard activities which might involve medical support. These forecasts were then modified to account for the effect of evolving biomedical technology.

Finally, taking all of the work into account, quantitative analyses were conducted considering both the evolution of medical developments important to the Coast Guard and each key biomedical development was assigned a probability of occurrence within the 25-year time frame. For certain selected variables, quantitative forecasts were produced. The forecasts of the variables were produced using trend impact analysis, a technique developed by The Futures Group. This approach combines mathematical projections and human judgment about future events.

In Trend Impact Analysis, extrapolated trends are modified to account for the impact of unprecedented future developments that, if they occurred, would deflect the trends. This computer program involves the following steps:

1. Development of a mathematical extrapolation or baseline forecast. The historical data of the trend under consideration are fed into a computer and the TIA program selects from a set of 15 equations the curve that most closely fits the past trend. The curve is extended into the future, generating the mathematical extrapolation or baseline forecast.

2. Development of a list of potential future events. The point of these events is to capture significant ways in which the future environment of the trend will differ from its past environment. In our study, of course, these events were derived from the literature searches, the workshop, and the in-depth studies.

3. Assessment of the likelihood of occurrence of each event. Each event is assigned a percentage probability of occurrence by a given year or years. Probabilities are optimally the consensus of opinion of people who are considered knowledgeable about the issue at hand; we utilized all of our references to obtain these judgments, but, in the end, they were provided by members of the staff performing the research.

4. Assessment of the individual impacts of the events. Each event is assumed to have occurred and an assessment is made as to how much and in which direction its occurrence will move the baseline forecast. Impacts are best developed by using the judgment of people who are experts in the field. Impacts were assessed as the result of our in-depth studies.

5. Assessment of each event's timing in its impact on the trend. Each event is assumed to have occurred and an assessment is made as to how many years will pass until its impact on the trend is first felt, how many years until its maximum impact is felt, and how many years until its steady-state impact is realized.

6. Computerized manipulation of the baseline forecast based on the assessments of probability, impact, and timing of the events. For each event, the TIA program multiplies the probability the event will occur in each year by the impact

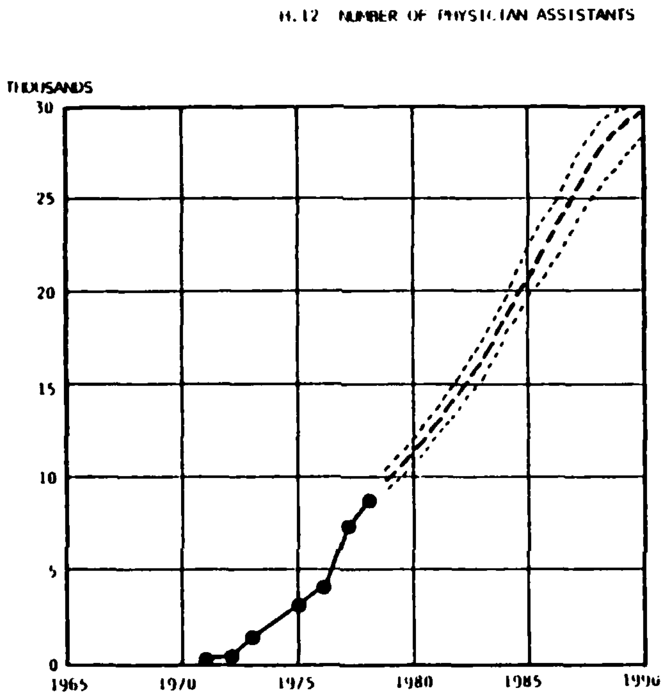
its occurrence in that year would have on the baseline. The change in baseline forecast is then computed as the sum of all the products of probabilities and impacts for all the events.

Figure 1-3 shows a typical TIA run; in this instance, a forecast of the number of physician assistants.

Chapter 7 of this report presents the results of these analyses.

prospects

H.12 NUMBER OF PHYSICIAN ASSISTANTS*



Source of historical data: estimate by the American Medical Association.

PHYSICIAN ASSISTANTS (THOUSANDS)

HISTORY

1971	0.19
1972	0.59
1973	1.60
1975	3.00
1976	4.10
1977	7.20
1978	8.80

FORECAST

	lower quartile	mean	upper quartile
1979	9.12	9.77	10.41
1980	10.55	11.19	11.85
1981	12.02	12.57	13.37
1982	13.77	14.47	15.24
1983	15.65	16.36	17.34
1984	17.65	18.43	19.71
1985	19.71	20.61	22.19
1986	21.81	22.87	24.78
1987	23.97	25.21	27.47
1988	26.16	27.63	30.25
1989	28.40	30.12	33.12
1990	30.42	32.31	35.67

*A physician assistant is defined as a skilled person qualified by academic or practical training to provide patient services under the supervision and direction of a licensed physician who is responsible for the performance of that assistant. Does not include nurse practitioners.

FIGURE 1-3. EXAMPLE OF A TIA RUN.

events used in impact analysis

EVENT NUMBER	FORECAST	ESTIMATED PROBABILITY BY YEAR SHOWN		YEARS TO FIRST IMPACT	YEARS TO MAXIMUM IMPACT	MAXIMUM IMPACT (PERCENT)	FORECAST SOURCE NUMBER(S)
1242	Relative oversupply of physicians in primary care exists.	.70	1990	3	10	- 10	3197
384	Less specialization among M.D.s, with greater proportion of primary-care doctors emerging in comparison with those already in practice.	.60	1980	3	10	+ 5	1119,1128, 1130,1138, 1139,2236, 3197
491	Comprehensive national health insurance program enacted to provide coverage for all groups. Poor and aged are covered by government; workers covered by private plans.	.76	1990	3	5	+ 10	2404
583	A number of studies confirm that primary care practices with physician assistants experience substantial gains of revenue over expenses.	.50	1980	2	10	+ 8	1658,1659
990	Physician assistants are recognized and accepted by the medical community, patients, and third party payers: use of these extenders is greatly expanded	.50	1985	0	5	+ 15	2545,2546, 2547,2548, 1656
073	Private and public insurers adopt policy of reimbursing P.A.s directly for certain medical services.	.75	1979	3	10	+ 12	3199,3202, 3203

FIGURE 1-3. (CONT.)

2. EMERGENCY MEDICINE

Introduction

There are a number of professional and governmental activities that have encouraged growth in the practice of emergency medicine. The National Highway Safety Act of 1966 authorized the Department of Transportation to provide funds for ambulances, communications, training programs and statewide planning of emergency medical services. By the end of the 1960s professional organizations were becoming increasingly active in emergency medicine and the American Trauma Society and American College of Emergency Physicians were founded. In November of 1973 Public Law 93-154, Emergency Medical Services Systems Act, was signed into law and authorized the expenditure of $185 million over a three year period. By 1975 the American Medical Association's House of Delegates was recommending that emergency medicine be considered a new specialty. In 1978 Congress had renewed emergency medical service legislation authorizing $200 million for system development, $15 million for research, $40 million for training, and $14 million for burn injuries. This recent attention and growth has been remarkable in light of the early deficiencies of our system of delivery of emergency medical care.

Early deficiencies in delivery of emergency medical care. In 1966, the National Association of Science declared trauma as "the neglected disease of modern society."[1] In 1972, the NAS Committee on Emergency Medical Services stated: "Emergency medical service is one of the weakest links in the delivery of health care in the nation."[2] Data showed that only 65 percent of the country's ambulance attendants were trained to the advanced first aid level of the American National Red Cross, and that 10 percent even lacked training in basics of first aid. Not only did the ambulances consist of hearses, limosines, or station wagon types, with no room to accommodate the treatment of the patient, but also many of the vehicles did not have the equipment recommended by the American College of Surgeons. Many ambulances did not have radio communications with dispatchers, hospital staff, the police department, or the fire department. The span of physicians rarely extended beyond the emergency room itself and care given at the emergency scene and in the ambulance was often of low quality.

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[1]National Academy of Sciences, National Research Council, Division of Medical Sciences, Report, "Accidental Death and Disability: The Neglected Disease of Modern Society," Washington, D.C., 1966.

[2]National Academy of Sciences, National Research Council, Division of Medical Sciences, Committee on Emergency Medical Services, "Roles and Resources of Federal Agencies in Support of Comprehensive Emergency Systems," Washington, D.C., National Research Council, March 1972, p. 3.

The most frequent problems that bring patients to the emergency room are heart attacks, injuries received in automobile accidents, poisonings, burns, and falls. According to the National Safety Council the death rates from motor vehicle accidents, falls, and fires have all decreased during the last decade. The death rate for heart attacks is also decreasing. Better emergency medical services have been given at least partial credit for these reduced death rates. Public education is no doubt having an impact on the use of emergency medical services. Widespread advertisement of systems such as the establishment of a single telephone number (911) for use in all kinds of emergencies encourages use of emergency services.

Financial arrangments have also encouraged use of emergency room services. Insurance companies traditionally have reimbursed policyholders for expenses incurred at a hospital but not for those incurred in a physician's office. Eventually substantial numbers of policyholders caught onto this discrimination and began taking their minor emergencies to the hospital rather than to their physician's office. The insurance companies have recognized the inflationary nature of this policy and are beginning to correct it. Currently Standard Oil of Indiana's Amoco unit is test marketing a plan that provides its credit card holders with a special hospital bond that guarantees payment for up to $250 of emergency room expenses incurred 100 miles or more away from home. This too will make it easier to use hospital emergency room facilities.

A recent Roper poll reports that two out of three Americans now regard hospital emergency rooms as interchangeable with their physician's offices for general treatment. It is the lure of round-the-clock availability as well as the greater equipment resources of the hospital that is shaping the public's attitude. Some doctors foresee increasing competition between hospitals and private physicians in providing primary care.

While the past trend in number of emergency outpatient visits has shown remarkable growth (see Figure 2-1),[3] it appears that the growth is slowing.

Among the future developments that will affect the trend in use of emergency facilities are

- use of air bags in automobiles and other automobile-accident reducing strategies

- general increase in the size of the population as well as increases (at a higher than historical rate) in the accident prone population segment

- better and earlier diagnosis of heart disease, and therapies for heart disease lessening the number of heart-related emergencies

- national health insurance.

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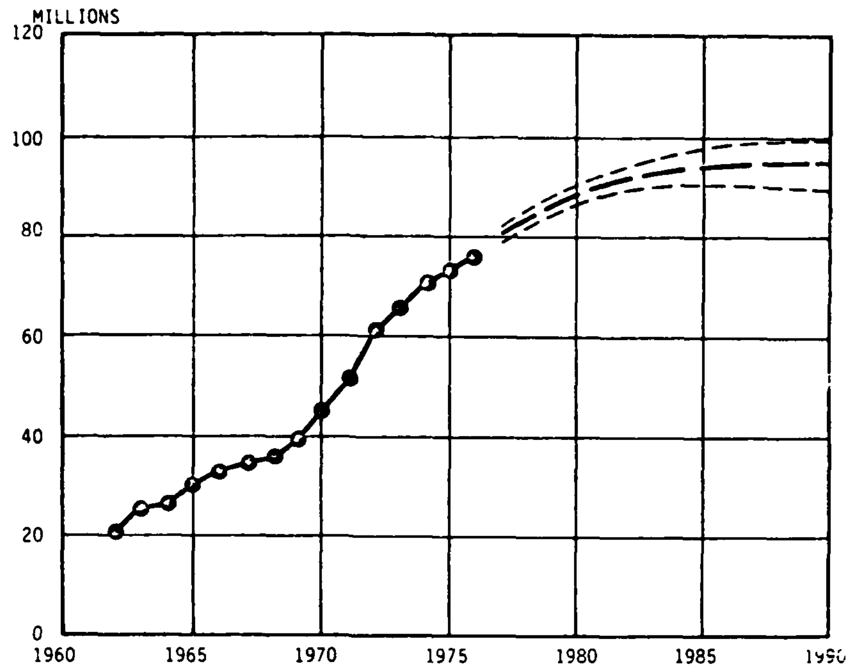
[3]This forecast was produced by TIA, a process described in Appendix B.



Source of historical data: American Hospital Association: Pre-1971 data from *Hospitals Guide Issues* published each August 1; subsequent data from *Hospital Statistics* (Chicago, Illinois: American Hospital Association), various editions.

FIGURE 2-1. NUMBER OF EMERGENCY OUTPATIENT VISITS.

Progress

As mentioned earlier, through funding of the National Highway Safety Act of 1966, the Department of Transportation created a new class of health professional: the emergency medical technician (EMT). The intent of this section of the act, of course, was to reduce highway fatalities by improving emergency health care at the scene of an accident. EMTs received 81 hours of course work in emergency care, and, on graduating, earned the right to be called EMT. The training program included instruction on how to maintain an airway, treat hemorrhage and shock, administer cardiopulmonary resuscitation, and immobilize a patient with multiple trauma injuries for transportation to a hospital.[4] By 1977, approximately 116,000 EMTs (65 percent of the total number of people trained as EMTs) had been certified by the National Registry of Emergency Medical Technicians. The number of registrants is increasing at the rate of 2000 per month.[5]

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[4]Alfred M. Sadler et al., Emergency Medical Care: The Neglected Public Service (Massachusetts: Ballinger Publishing Company, 1977).

[5]"Emergency Medical Services at Mid-Passage," Report of the Committee on Emergency Medical Services, Assembly of Life Sciences, National Research Council, National Academy of Sciences, Washington, D.C., December 1978.

To indicate how this new specialty and emergency medicine in general have grown:

- Of the 287,000 ambulance personnel, 262,000 are trained at the EMT-A level and another 12,000 have a minimum of 1000 hours of advanced paramedic (EMT-P) training.

- As of March 1978, half of the states had laws covering ambulance attendant training, and 40 states had passed paramedic legislation.[6]

- the federal government is establishing a network of 300 continuous Emergency Medical Service (EMS) systems across the United States. Already, the areas have been defined, and 278 of the 300 have been funded and 140 have become operational and are organized by regions, counties and towns. Others are structured to serve on a city-wide basis.[7]

- Of the 300 U.S. emergency medical service regions, 40 are capable of life support, with specialized trauma, cardiac, neonatal, pediatric, and burn treatment facilities; mobile intensive care units, and allied health professionals trained in invasive medical procedures; and biomedical telemetry.[8]

- Nearly all states have enacted legislation supporting emergency medical systems vehicles and personnel, and most have founded EMS offices.

- Well-designed ambulances are now the rule rather than the exception; all 27,000 ambulances meet ACS equipment standards.

- Twenty-four helicopter ambulance services are available through the Military Assistance to Safety in Traffic (MAST), and state, municipal, and private air transport services.[9]

An Emergency Medical Service system can vary to a great degree in different respects. It can be city or statewide; it can be managed by a state, county, or city health department, with a fire department or other local agency, with a private ambulance company, with a hospital or hospital

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[6] Medical World News, March 20, 1978, Vol. 19, No. 6, pp. 65-72.

[7] "Emergency Medical Services at Mid-Passage," December 1978.

[8] Medical World News, pp. 65-72.

[9] Ibid.

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[8] Medical World News, pp. 65-72.

[9] Ibid.

association, with an EMS committee, with a civil defense office, with a council of governments, or any other body that will assume responsibility. Support of the system can be from local taxes, voluntary contributions, cost-sharing arrangements among providers and users, fees, subsidies, subscriptions, or by some combination of these; however, many still depend on federal grants.

Today, it is apparent that most emergency care patients at the scene and en route to the hospital receive high-quality care administered by the EMTs. The advancements in radio communication and of telemetry have given increased responsibility to the EMTs and have broadened their contribution to the emergency care medical system. Physicians, nurses, and paramedical personnel have been better trained in emergency medicine, which has resulted in changes of the staffing in the emergency departments of hospitals. The interest in emergency medicine has resulted in the founding of trauma research centers and professional organizations such as the American Trauma Society, and many communities have EMS councils. A set of standards for emergency medical systems was established in the Emergency Medical Systems Act of 1973.[10]

In 1979, increased recognition was awarded emergency medicine with the certification of the recognition of Emergency Medicine as a specialty.

There is every indication that this activity has resulted in real improvement in emergency patient survival rates.

- The 50 percent reduction in mortality by motor vehicle accidents in Illinois has been due to better communication, effective on-the-scene care and the catagorization of hospitals' emergency departments.

- Dr. Richard S. Crampton of the University of Virginia in Charlottsville, reported in 1974 that prehospital coronary death rates had fallen 26 percent and ambulance coronary death rates, 62 percent, three years after a community-wide CPR program and prehospital emergency cardiac care began there.[11]

In short, in the space of a decade, the field has made enormous progress, in both quantitive (e.g., numbers of people involved, equipment, etc.) and qualitative (e.g., survival rate) terms. This progress is probably more rapid than that achieved by any other emergency medical specialty.

Presently, Medicare Part B coverage usually provides PA reimbursement only when the PA's services are furnished as an incident to a physician's professional service. Thus, personal supervision by a physician is required.

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[10] "Emergency Medical Services at Mid-Passage," December 1978, pp. 103.

[11] Medical World News, March 20, 1978, Vol. 19, No. 6, pp. 65-72.

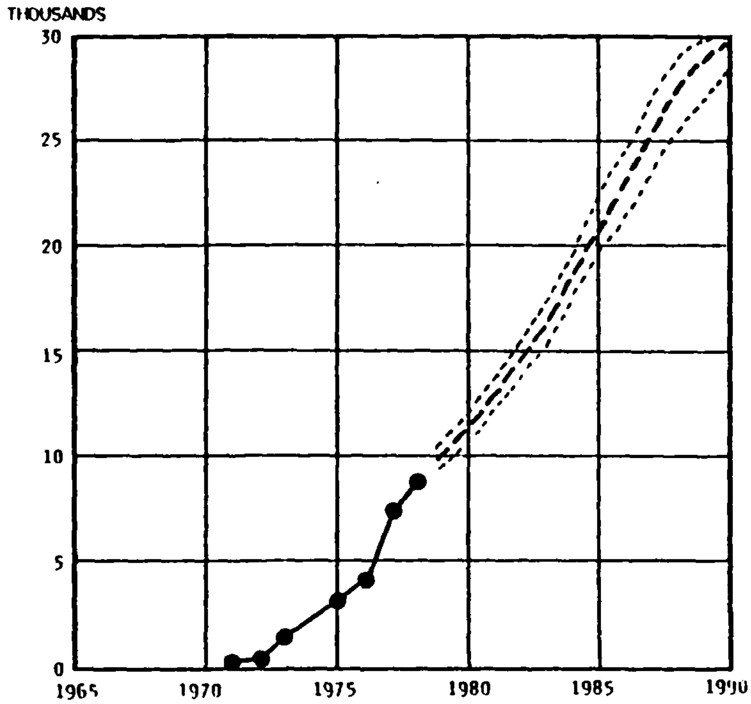
In addition, reimbursable services include only services normally delegated by a physician, not services that are traditionally rendered by physicians. Medicaid regulations permit wider PA reimbursement, covering services rendered under general physician supervision and in accordance with applicable state laws. Each state Medicaid agency has ultimate responsibility for determining reimbursable services. To address the discrepancy between the goal of supporting PA training and the Social Security Administration denial of payment for their services, the Social Security Administration has designed a large experiment to examine this issue. Significant delays have postponed any meaningful results until next year. Financial problems threatened the existence of rural health clinics in Appalachia because of the unavailability of Medicare reimbursement to PAs. In December 1977, the Rural Health Clinic Services Act (PL 95-210) was signed into law to allow Medicare and Medicaid payment for NPs and PAs in rural health clinics in the United States. Facilities certified as rural health clinics are covered under Medicare and Medicaid for medical services furnished by PAs and NPs. Nearly 2600 facilities are potentially qualified; to date, 215 have been approved for participation. The new law also set up a pilot project of direct PA reimbursement in physician-directed clinics in medically underserved urban areas.

Physician Assistants and Nurse Practitioners

Medical specialties other than EMTs, should be considered in this review of emergency medicine: physician assistants (PA) and nurse practitioners (NP). Both specialties are growing and will alleviate the caseload for primary physicians. We anticipate that there will be considerable flow between PA, NP, and EMT specialties.

The number of practicing physician assistants is forecast to nearly quadruple by 1990 from its 1978 level of approximately 8800 as acceptance of PAs grows, direct insurance reimbursements become available, and demand for medical services expands. (See Figure 2-2.)[12] The uneven distribution of physicians and the thrust toward lower medical costs have contributed to the rise in physician assistants of the past decade. PA and nurse-practitioner (NP) programs were fostered by deficiencies in primary care, particularly in rural areas, and rising health care costs. Professional relationships with the medical hierarchy remain a problem, and medico-legal questions will need to be resolved before their future success is assured. Funding for training programs began in the 1960s; about 50 to 70 percent of all physician extender programs (PAs, nurse-practitioners, and Medex) receive federal funding support. Training programs for PAs vary greatly in terms of entrance requirements, curriculum content, institutional settings, and program title or name. Most training programs are two years and nearly all train assistants to the primary care physician. The majority receive federal government support; some programs get assistance from state government and/or private foundations.

[12]This forecast was also derived by TIA.



Source of historical data: estimate by the American Medical Association.

FIGURE 2-2. NUMBER OF PHYSICIAN ASSISTANTS.

Since the PA movement is largely sustained by federal government funds, future supply is particularly sensitive to changes in Congressional mood. If federal funding is maintained at its present level through 1990, PAs could increase almost seven-fold. If funding triples in 1980, the total number of PAs in 1990 would be increased ten-fold over the 1975 level. If funding is halved in 1980, the increase would be less than five-fold. When these figures are compared to projections for active physicians, it is apparent that PAs will continue to represent only a small share of total primary care manpower. The Health Professions Educational Assistance Act of 1976 (PL 94-484) extends PA education programs which were initially authorized as demonstration programs under 1971 legislation. The intent of the federally supported PA programs is to educate assistants to the primary care physician and orient their employment in ambulatory care in health manpower shortage areas. In 1977 there were 55 accredited programs for primary care PAs; about one-fourth are based in medical schools, one-fifth are in schools of allied health, another one-fourth are in medical centers, and about 30 percent are in academic centers with clinical resources. An HEW Work Group has recommended continued support of PA and nurse-practitioner educational programs, but adds that it is too soon to determine whether these programs should be standardized or if one type of program is superior to another.

A recent survey by the Association of Physician Assistant Programs showed the average graduate to be about 30 years old. Almost one-third of all graduates in 1976 were women (from 12.5 percent in 1969) although ex-military medical corpsmen still form the single largest group of graduates. Most PAs were in practice with office-based physicians. Seventy-five percent of the 1976 graduating class found employment within two months of graduation. The vast majority of PAs are white; about one-third are employed in the South, probably because most of the first PA training programs were begun in that region. PAs are working in 49 states, although most are concentrated in larger states or states with well-established PA programs. Primary care PAs tend to locate in non-metropolitan communities with less than 50,000 population in higher proportion than primary-care physicians. More than 8000 nurse-practitioners have graduated from training programs. About 20 percent are trained in adult primary care, another 20 percent in family care programs.

Mobile Emergency Care

Emergency demand can be categorized in the following manner:

1. Life Threatening. Death will occur if there is not immediate treatment. Body processes and vital signs are not normal. Severe hemorrhaging, severe multiple trauma, acute respiratory failure, cardiac arrest or pulmonary edema, peripheral vascular failure or collapse (shock).

   Limb Threatening. A state which threatens loss of limb or limb function, such as gangrene, traumatic amputation, or laceration, severe crush injuries, open or displaced fractures.

2. Urgent. Life or bodily functions are threatened if medical care is delayed more than several hours. Urgent cases would include major open wounds and lacerations; fractures, head injuries with skull fractures, loss of consciousness or loss of vision; burns other than minor poisoning; high fever; severe abdominal pain; severe chest pain; severe difficulty in breathing; heart irregularities; or overdose of medication.

3. Routine. Patient's life or usual activities would not be immediately threatened by referral to an alternative facility for treatment at a later time. For example, superficial injuries, lacerations, sprains, dislocations, chronic complaints, respiratory infections, gastrointestinal conditions, genito-urinary tract conditions, rashes, nervousness and depression, headache, or blurred vision.

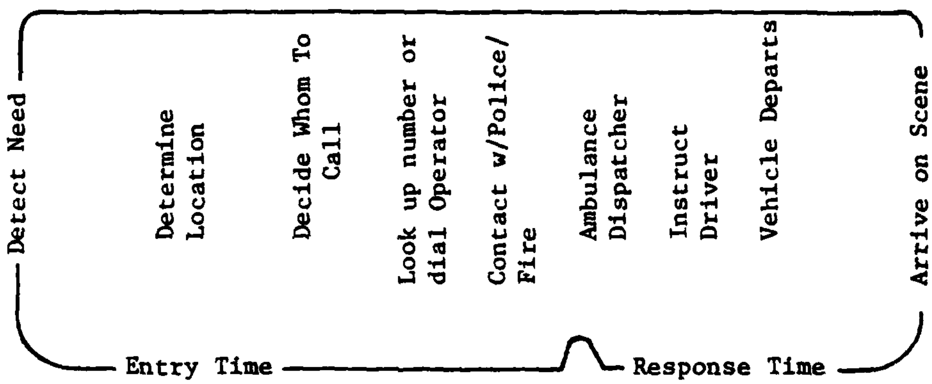
4. Transfers. Patient transported between residence and institution or between institutions. No threat to life is involved; transfer can be scheduled routinely.

5. Dry Run. No patient found at scene of incident.[13]

Time of response in emergency situations, is, of course, crucial. In analyzing emergency systems, two time delays are generally measured: "entry time" and "response time."

Entry time begins when medical aid is first sought and extends until the time a person authorized to send a vehicle is contacted. Response time begins when the authorized person sends out an ambulance and extends until the vehicle arrives at the scene of the emergency. This time scheme can be shown diagramatically by the following:

Critical Time



Response time is easily measurable and is a variable that can be evaluated in determining the quality of an emergency medical system.[14]

The DHEW specification is that an adequate response is one in which "95 percent of cases are responded to within 10 minutes in urban settings and 30 minutes in rural areas.[15]

Ambulances and Helicopters. The generally accepted definition of an ambulance is

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[13] "Estimating Demand for Emergency Transportation," Medical Care, September 1977, Vol. 15, No. 9, pp. 738-749.

[14] Sadler, pp. 88-89.

[15] Geoffrey Gibson, Health Services Research, Vol. 11, No. 1, Summer 1976, pp. 105-111.

"A vehicle for emergency care which provides a driver compartment, and a patient compartment which can accommodate two emergency medical technicians and two litter patients so positioned that at least one patient can be given intensive life-support during transit; which carries equipment and supplies for optimal emergency care at the scene, as well as during transport, for two-way radio communication, for safeguarding personnel and patients under hazardous conditions, and for light rescue procedures; and which is designed and constructed to afford maximum safety and comfort, and to avoid aggrevation of the patients' conditions, exposure to complications, and threat to survival.[16]

Ambulances now generally have adequate equipment to meet an emergency and to transport the patient from the site to an emergency room.

In 1961, the Committee on Trauma of the American College of Surgeons established a list called "Minimal Equipment for Ambulances," which was revised in 1966. The American College of Surgeons has upgraded the list to include "Essential Equipment for Ambulances" (see Table 2-1).[17]

Current trends suggest that the ambulance of the future may well be "an emergency room on wheels." This vehicle would include all necessary life-saving and supporting equipment. If planned properly, an ambulance would be able to serve as an emergency room at the scene of the accident and also serve as a mode of transportation to the hospital. Also, this future ambulance could act as a triage center, and the conventional ambulances could take prepared patients to the hospital. Dr. Herbert Warm, of Vista, California, a retired U.S. Naval Research Captain has in mind a Travco 270 executive unit. The twenty-even-foot long, eight-foot wide motor home could be converted to an emergency vehicle quite easily. It would have its own gas, water, and electricity and plenty of room for a team of medical personnel to treat several patients at once. He recommends that the community should pay for and operate the vehicle but it should be based at a general hospital.[18]

Helicopters, as airborne ambulances, provide very rapid response capability and permit access to otherwise inaccessible areas; they are, however, expensive. Nevertheless if their use increased, response would be more rapid in many instances and the number of fatalities would diminish. For

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[16] John W. Camden, Emergency Medical Services, (Westport, CT: Technomic Publishing Co., Inc., 1972).

[17] "Essential Equipment for Ambulances," booklet, Committee on Trauma, American College of Surgeons, September 1977.

[18] Katherine Traver Barkley, The Ambulance, (New York: Exposition Press, 1978).

TABLE 2-1. ESSENTIAL EQUIPMENT FOR AMBULANCES.

1. Portable suction apparatus with wide-bore tubing and rigid pharyngeal suction tip.
2. Hand-operated bag-mask ventilation unit with adult, child, and infant-size masks. Clear masks are preferable. Valves must operate in cold weather, and unit must be capable of use with oxygen supply.
3. Oropharyngeal airways in adult, child and infant sizes.
4. Mouth-to-mouth artificial ventilation airways for adults and children.
5. Portable oxygen equipment with adequate tubing and semi-open, valveless, transparent masks in adult, child, and infant sizes.
6. Mouth gags, eith commercial or made of three tongue blades taped together and padded.
7. Universal dressings, approximately 10 inches by 36 inches, compactly folded and packaged in a convenient size.
8. Sterile gauze pads, 4 inches by 4 inches.
9. Soft-roller self-adhering bandages, 6 inches by 5 yards.
10. Roll of aluminum foil, 18 inches by 25 feet, sterilized and wrapped.
11. Two rolls of plain adhesive tape, 3 inches wide.
12. Two sterile burn sheets.
13. Hinged half-ring lower extremity traction splint (ring 9 inches in diameter, overall length of splint 43 inches) with commercial limb-support slings, padded ankle hitch, and traction strap.
14. Uncomplicated inflatable splints.
15. Short and long spine boards with accessories.
16. Triangular bandages.
17. Large-size safety pins.
18. Shears for bandages.
19. Sterile obstetrical kit.
20. Poison kit.
21. Blood pressure manometer, cuff, and stethoscope.
22. Compartmentalized pneumatic trousers with inflation equipment.
23. Two-way radio allowing direct communiction between the EMT and the emergency department of the hospital.
24. Compartmentalized pneumatic trousers.
25. Two-way radio for communication between EMT and emergency department.
26. Tracheal intubation equipment.
27. I.V. solutions in plastic bags.
28. Medication with syringes and needles.
29. A cardioscope and defibrillator.
30. Telemetry equipment.

example, the military reported a death rate of only 2 percent for combat casualties rescued and transported to medical facilities by helicopters.

The helicopter may be considered to provide a specialized extension of the ambulance's capabilities, particularly in the following situations:

- the seriously ill or injured where time is of the essence.
- for transportation of health professionals to locations where treatment is required immediately.
- for access to sites inaccessible to ambulances.

The helicopter should not be used to transport victims to built-up urban areas, in such cases, ambulances can match the helicopter's ground time.[19]

New Equipment Directions

Hand-held vital-signs monitor. A hand-held vital-signs monitor, miniaturized by hybrid integrated-circuit technology, has been designed to process and display body temperature, heart rate, and breath rate. Systolic and diastolic blood pressure, processed by external circuits, can also be displayed. The hybrids have been designed, built and tested by researchers working for the Lyndon B. Johnson Space Center. Its essential elements are a liquid-crystal display, a four-channel two-input digital switch, and six new hybrid circuits, including: a temperature monitor; an ECG amplifier; an impedance pneumograph and respiration-rate signal conditioner; a heart/breath rate processor; a liquid crystal display driver, and a clock circuit. Each of the circuits can be used independently for other applications.[20]

MAST trousers. MAST trousers are most commonly used to prevent irreversible shock in trauma on the scene, en route, and in the emergency room. The trousers are used in cases of hypovolemia other than trauma, i.e., G.I. bleeders, massive dehydration, and sepsis. Also, they are used when there is hypotension secondary to vascular dilation, i.e., drug effects, allergic reactions, spinal shock, and anesthesia.

The device (1) prevents further blood loss, (2) increases venous return, (3) provides immediate auto transfusion, (4) restricts blood flow to the upper body, (5) provides for a more orderly transport and better triage, (6) can be used by a paramedic not having IV capabilities, and (7) is designed to obtain stability in the home, street, and civilian locale.

The trousers are simple, at a low cost, fast acting, and reusable. They are of apparent merit in life-threatening situations. Also, they may be entrusted to trained paramedics. One may consider the device as a valuable research tool. The use of the trousers is one answer to pre-hospital shock therapy.

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[19] Camden, p.17.

[20] For further information, contact: George A. Rina; 2025 Iliss, Denver, CO 80280; (303) 753-1964.

In the future, the trouser may be used with CPR. The venous output when CPR is used is 35 percent; the new technique would increase the venous output 50 to 60 percent. Perhaps the trouser will be transparent in the future. An idea is to have an attached label to the trousers that says "Do Not Rapidly Deflate," an instruction sometimes unheeded.

Battery-powered pump oxygenator. Mechanical cardiopulmonary bypass may be utilized to resuscitate highly selective patients who are in extremis. The addition of a battery mode to drive the pump oxygenator allows for portability from one area of the hospital to another. With the extensive availability of pump teams for elective heart surgery, cardiopulmonary bypass is applicable to patients with emergency conditions.

The addition of a portable, battery-pack unit provides the possibility of not only one transfer within a hospital, but perhaps transfer of critically ill patients over long geographic distances.[21]

Heart Aid™. Heart-Aid is a new device that automatically reports a cardiac arrest victim's status and corrects rhythm disorders by defibrillation and pacing. The computerized machine, the size of a typewriter, consists of a logic circuit mated to a cardiac defibrillator and external pacer. Patient input is via electrodes and an ultrasensitive respiratory sensor, which are connected to an oval airway, and a prejelled abdominal electrode completes the circuit. The system processes the data, which is a measure of the presence or absence of breathing, and the ventricular rate. If breathing is absent and the ventricular rate is above 200 per minute, a 335 watt second defibrillating charge is automatically delivered to the patient via the oropharyngeal pathway. Prior to the delivery of the charge, a seven second warning is activated for the operator to stand clear. If breathing is absent and ventricular rate is less than 25 per minute, a 0.05 watt second pacing current is activated and external cardiac pacing begins. The cycle of events for 30 minutes is recorded automatically on a tape cassette for later transcription as a permanent record.[22]

Presently, there are questions concerning its operation, such as its efficacy of external pacing and the safety of the airway. However, these questions may pave the way to future investigation and possible improvements.[23]

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[21] Kenneth L. Mattox and Arthur C. Beall, "Application of Portable Cardiopulmonary Bypass to Emergency Instrumentation," Medical Instrumentation, Nov.-Dec., 1FF, Vol 11, No. 6, pp. 347-349.

[22] Cardiac Resuscitator Corporation, Portland, Oregon.

[23] "Little Resuscitator Takes on Big Job--Maybe Too Big," Medical World News, Vol. 20, No. 22, October 29, 1979.

Digital sphygmomanometer. The digital sphygmomanometer is an electronic instrument designed to increase the reliability and efficiency of blood pressure measurements. The sphygmomanometer does not require a stethoscope or the training and experience the stethoscope technique requires. Instead, a special electronic sensor mounted in the cuff detects the Korotkoff sounds. All the attendant needs to do is wrap and inflate the cuff; the actual measurement, including deflation of the cuff, is completed automatically. Presently, steps are being taken in devising a totally automated system (no bulb).

Within the next five years, a unit will be made that will work on a moving vehicle or treadmill. Also, in the future, there will be a computerized setup that will be able to differentiate between vibrations and K sounds, i.e., it will be programmed to eliminate all sounds.

Esophageal obturator airway. The EOA, a device designed for use in the management of cardiopulmonary arrest, obstructs the esophagus while simultaneously ventilating the lungs.[24] The device consists of a soft plastic tube with the lower end occluded bluntly; holes are cut in the tube above the laryngeal area. It fits tightly in a mask, and on the lower end, there is a balloon inflated with 35 c.c.'s of air. The mask provides for a tight seal at the nose and mouth so that air forced into the tube goes directly into the trachea.[25] Physiological studies indicate that vital capacity, blood gases, and pH were comparable to those obtained with the use of the endotracheal tube. The insertion of the EOA was more rapid (mean 6 Sec. vs 20 sec.), more accurate (98 percent vs 48 percent) and easier to teach to paramedical personnel. The study concluded that whenever optimal conditions for endotracheal intubation are unavailable, the EOA should be first choice in the managment of the airway in aneflexic, apneic patients.

A byproduct of the EOA is the esophagogastric tube, a modification of the EOA. There is a centrally placed gastric tube which is passed through the esophageal tube into the stomach and is used to aspirate stomach contents, thereby decompressing it.[26]

Pulse/egg monitoring system. A pulse EKG monitor is now available which measures and displays all data digitally and in real time. The monitor utilizes a standard photo-electric finger sensor to detect pulse rate. The system is designed for stress-testing, health check-ups, and routine patient monitoring. The machine is designed to be transported particularly for use by the EMTs.

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[24] T.A. Don Michael, Medical Instrumentation, November-December 1977, Vol. 11, No. 6, pp. 331-333.

[25] American College of Emergency Physicians, Scientific Assembly, October 1-4, 1979.

[26] Medical Instrumentation, November-December 1977.

The spray-on burn bandage. Abbott Laboratories have recently announced a spray-on bandage to be used in burn cases. Their bandage represents a direction which may be more common in the future in emergency manners. The spray-on burn bandage provides an effective barrier to the environmental contaminants; it allows passage of water vapor in both directions. This property permits the use of water soluble antibiotics to be applied through the dressing. The bandage is formed through the use of two chemically nonreactive components: polyethylene glycol and a proprietary powdered polymer (poly-2-hydroxyethyl methacrylate). A physician first prepared the wound and then sprayed the liquid solvent directly onto the wound. The powdered polymer is then applied to the solvent and additional layers are built up immediately. The dressing is flexible and transparent.[27]

Artificial blood. Artificial blood has been and continues to be an elusive goal of pharmaceutical researchers. The intent is to provide a fluid which would augment normal blood supply rather than replace it totally. Special fluid could be useful not only in solving a blood shortage problem, but could be employed during major surgery and, most importantly, as an emergency oxygen-carrying plasma substitute to be used in emergency medicine. Researchers generally believe that artificial blood is at least five years away. Current research involves screening of various materials including fluorochemicals which can be eliminated from the body through normal metabolic processes.[28]

[27] Biomedical Technology, November 30, 1978, p. 121.

[28] Biomedical Technology, August 31, 1978, p. 86.

3. THE REMOTE TRANSMISSION OF HEALTH DATA

Introduction

Health care has been markedly facilitated and improved by the development of methods and systems for transmitting biomedical information between distant locations. The various methods and systems employed for the transmission of information over a distance are grouped together under the generic term telecommunications; when the information being transmitted is of biological and/or medical relevance, the descriptive term is biomedical telecommunications.

Telemetry is a more specific form of telecommunication meaning measurement from a distance. The implication here is that the data being transmitted have quantitative, as well as qualitative, significance. For example, a health-related method of measurement, such as an electrocardiogram, contains information about heart rate, the duration of a cardiac cycle, the amplitudes of various components of the cycle, the durations of each component, and the variations in any of these variables from cycle to cycle. Telemetry includes transmission by radio, telephone, or television. Telemedicine is the practice of medicine using telecommunications. The patient is usually located at a long distance from the physician who is receiving data of diagnostic importance and directing treatment.

Recent advances in biomedical telecommunications have been impressive. The accomplishments in this area have been primarily due to the design and development of medical communications systems. Careful functional analysis of the communications requirements of various areas of medical practice have given rise to important applications of communications technology to the practice of medicine. Scientific and technological advances have also been important in extending the range of applications in biomedical research and systems design.

Technological advances in our abilities to transmit health data between distant locations have markedly improved the quality and availability of health care. Emergency and critical care have progressed through radio communications approaches such as telemetry. General medical care has improved in geographic regions with low population density and few physicians, as a result of satellite communications systems. Medical diagnosis, treatment, education, research and administration also have benefited from advances in telecommunications technology.

The development of methods for remote monitoring of selected aspects of hazardous and potentially hazardous environments and of the effects of these environments upon human beings and animals has improved the capability to live and work in these environments, and to acquire a measure of control over them. Space flights, deep oceanic investigations and other activities bringing man into highly stressful and demanding environments and situations have been made safer and, in some cases, possible through advances in biomedical telecommunications and telemetry.

Finally, advances in remote monitoring of human physiological responses to tasks and occupations have improved understanding of means for producing various levels of physical and psychological stress and have contributed to understanding the manner in which different kinds of work affect different individuals. Through increased understanding of the interactions between human factors and task requirements, occupational stress can be better controlled and the quality of the work environment and human health and performance can be improved. This could prove useful to the Coast Guard in setting physical standards for more stressful billets (as is presently done for aviators and divers), in determining minimum fitness levels for entrance and retention standards, and in reviewing individual cases during boards of medical review.

Telecommunications in Emergency Medicine - The Present

The most well known current system of emergency telecommunication exists in Maryland. The Maryland Emergency Medical Services Communication System (EMSCS) integrates the medical resources of Maryland for the purpose of effectively handling medical emergencies. The system is organized on a hierarchical basis with three levels of function: local (county or metropolitan), regional, and statewide. There are 23 county centers and one metropolitan center which is located in Baltimore. Currently, there is only one regional center which is in Region III, where most of the major medical facilities are located and the population density is probably highest. The statewide center is also located in Baltimore. The local centers integrate county medical resources. The one regional center integrates the many medical resources in Region III. The statewide center ties together the medical resources of the whole state.

The local communications capabilities. Each county has a central alarm which is staffed around-the-clock by specially trained dispatchers. Each central alarm has its own telephone number. Anyone in the county who is in need of emergency medical services can obtain help by calling this number. The trained dispatcher receives the telephone request and decides on the appropriate response. If necessary, the dispatcher sends the proper kind and number of mobile units to provide assistance. The local dispatcher is responsible for coordinating all ambulances operating within his or her county. Several central alarms also have the responsibility of coordinating the mobile units of other public service agencies such as fire departments, law enforcement, and civil defense agencies as well. The FCC has provided two UHF radio channels for dispatch and coordination functions. One of these is used by all mobile units operating within the state system, and is monitored continuously by all central alarms in Regions I, II, IV, and V.

The central alarm in each county of Regions I, II, IV, and V is equipped for arranging and coordinating in-county (in-city in the case of metropolitan Baltimore) communications among physicians, hospital personnel, ambulance attendants, and dispatchers. Several kinds of communications are thus made possible. A small sample of these is provided on the next page as examples.

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Sender	Receiver	Purpose
Ambulance Attendant	Physician	Request for advice and direction prior to moving patient.
Physician	Ambulance Attendant	Request for a description of patient's condition.
		Request for electrocardiogram data (by telemetry).
Ambulance Attendant Radiotelemetry	Physician Physician	Description of patient's condition. Display of patient's electrocardiogram.
Physician	Ambulance Attendant	Directions to begin cardiopulmonary resuscitation, and prepare to defibrillate patient.
Physician	Hospital	Arrange for emergency admission of patient. Voice description of patient's condition.
Ambulance Attendant Radiotelemetry	Hospital Hospital	Continuous transmission of electrocardiogram to hospital that will receive patient.

Physicians, hospital personnel, ambulance attendants, and dispatchers are able to exchange information for the purposes of: 1) making medical decisions, 2) directing patient transport and care, 3) making arrangements with hospitals to receive a patient, 4) preparing hospital staff concerning the condition of the patient they are about to receive.

Each county communications system has four major components: ambulance radio equipment, the county radio base stations, an Emergency Medical Services Communication System operating console located at the central alarm, and Emergency Medical Services (EMS) remote control consoles located in county hospital emergency departments.

Mobile radios are permanently installed in the ambulances of Regions I, II, IV, and V. Ambulance attendants carry lightweight portable transmitters to the patient's side. These portable transmitters have enough range to transmit to the permanent ambulance radio, which then repeats the information. Combination cardiac monitor/defibrillators can be connected either directly to the portable or to the ambulance radio via a control panel in the patient compartment or a different panel in the cab. The repeated information reaches the nearest base station, which then relays it to the

EMSCS operating console at the central alarm. From the central alarm, the information can be transmitted to an EMS remote control console at any county hospital. Information also can be transmitted in the opposite direction. Radios and telephones can be interconnected at the EMSCS operating console by a radio/telephone patch which provides for statewide intercommunication between mobile units, hospitals, and physicians. Trained communications operators at each central alarm execute switching functions that interconnect all combinations of senders and receivers of information. This relieves ambulance and hospital staff of the technical aspects of establishing, maintaining, and changing communication channels.

The FCC has provided eight UHF channels for medical communications such as telemetry. Of these, one or more is assigned to each county for regular use. Two alternate channels also are assigned to each county should they be required. Counties with common borders are assigned different channels for regular use to reduce interference among communications channels. One additional medical channel is assigned to every county in order to permit statewide communications.

The regional communications capabilities. Only one, Region III, is designed to have regional communications capabilities. Two factors may account for this. Region III has a high population density and, therefore, a higher frequency of medical emergencies than other regions. Region III has a greater wealth of medical resources than the other regions. Two major university medical centers with departments staffed and equipped to manage the most difficult, acute, and severe medical problems are located in Baltimore. Several medical centers that specialize in the treatment of severe burns, neonatal emergencies, and accidental amputations also are located in Region III. The regional subsystem here provides direct communication channels to a wide variety of medical expertise and specialized medical care facilities.

The Metropolitan Baltimore Emergency Medical Resource Center (EMRC) coordinates and controls the numerous and frequent medical communications taking place in Region III. EMRC is also staffed around-the-clock by personnel specially trained to operate a sophisticated control console that connects the radios of mobile units (Medevac helicopters and ambulance) to terminals in the region's hospitals. At four "Cardiac Consultation Centers," electrocardiogram telemetry from mobile units is interpreted by medical specialists, who provide direction to ambulance paramedics in the use of advanced life-support methods and equipment. At the same time physicians in these "Cardiac Consultation Centers" provide instruction to ambulance staff in the field, and the hospital emergency department that will receive the patient. They can simultaneously monitor the same telemetry data and the conversation taking place between Center consultants and the ambulance personnel. Thus, ambulance personnel can communicate verbally or transmit telemetry data to any Region III hospital facility through EMRC.

The EMRC continuously monitors the deployment of all of the region's ambulances and the ability of the region's emergency rooms and coronary care units to receive patients. This information is transmitted over direct data lines from the six central alarms in Region III to the EMRC and is displayed on a large wall map.

The statewide communications capabilities. The Systems Communications Center (SYSCOM) is located in Baltimore at the Maryland Institute for Emergency Medicine. It is staffed every day, 24 hours a day, by specially trained system communications operators who coordinate the use of the state's emergency medical service system's resources. The operators have the responsibility of deploying Medevac helicopters when necessary, and arranging admission to Specialty Referral Centers for all patients transported by helicopter. They also are responsible for performing the switching operations that provide a direct line between a physician anywhere in the state and a special medical consultant at any of Maryland's medical centers and Specialty Referral Centers.

Telecommunications in Emergency Medicine - The Future

The Maryland Emergency Medical Services Communications System is the most advanced system in the country. For this reason, it is an indicator of things to come. It is a model that other states, and perhaps the Coast Guard, can use in planning their emergency medical services systems. Some specific future developments that could clearly flow from the Maryland system are the following:

- Notification of an emergency to a central alarm through a radio-transmitter worn on an individual, or built into homes or automobiles (or sea vessels). The occurrence of the emergency will be detected by a special sensor that will automatically trigger the transmitter. The location of the signal generated in this manner will automatically be established by special equipment in the environment, and will then be transmitted to the central alarm. The proposals of Weller will give impetus to future developments in this important area.[1]

- Computer dispatching of aid to medical emergency victims. When the location of the victim reaches central alarm (this will be almost instantaneous), it will be fed into a computer immediately. The computer will continually have within its memory the exact locations and deployment patterns of all mobile units. Mobile units will continuously feed their locations back to the computer on a real-time basis. The computer will be carrying out the third function, coordination of mobile unit movements, as it performs its dispatch function.

[1] C. Weller, "Patient Location--A Desirable Adjunct for Patient Telemetry," Biotelemetry 5(1):45, 1978.

- Remote physician control of emergency care. This control will include not only coordination of widely distributed medical resources, but also the remote direction of assistants in increasingly complex medical procedures.

Factors in the Development of Telemedicine

In the future, there will be an increase in the kind and amount of biomedical data transmitted from a victim at the site of a medical emergency to a physician in a distant hospital. There also will be an increase in the number of medical emergencies in which biomedical data will be transmitted. Developments in this area will be determined by a number of factors.

One important factor was discussed with Dr. Robert J. Huszar, Director of the Bureau of Emergency Health Services in the New York State Department of Health. He was asked what kinds of data a consulting physician might find useful for making decisions concerning the treatment of a victim of a medical emergency. He thought that transmission of the electroencephalogram output with the electrocardiogram output would provide a consulting physician with a basis for deciding whether an emergency medical technician should attempt to convert ventricular fibrillation at the site of the emergency by applying a defibrillator. A lack of activity on the electroencephalogram when accompanying evidence of ventricular fibrillation on the electrocardiogram would confirm a need for immediate defibrillation by helping to rule out artifact in the ECG--the EEG would be particularly useful if defibrillation were controlled cybernetically. Again, the EEG would help confirm that the ECG output was not artifact. He also thought that a determination and transmission of pulmonary wedge pressure would be useful for making the decision as to whether fluid replacement should be initiated by the medical technician at the scene or during transport of the patient to the hospital. Finally, he believed that it would be of value to transmit data reflecting cardiac output. Critically low output would indicate the need for immediate fluid infusion or perhaps epinephrine infusion depending upon the patient's response to intravenous fluid infusion.[2]

Holzer presented a system for sending and receiving health data.[3] In this case, the data were transmitted over 30 miles, but technology can also provide for transmission over much greater distances. He found that physicians preferred color television to black and white for examining patients. They did not seem to be interested in having better resolution in the

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[2] Robert J. Huszar, Director of the Bureau of Emergency Health Services, New York State Department of Health, Private Communications, 1979.

[3] Walter H. Holzer, "Telemedicine: New Applications of Communications Technology," IEEE Transaction on Communications 22(5):685-88, May 1974.

picture (a new system has recently been developed that could provide much greater picture resolution and detail). They preferred the Phumbicon as opposed to the vidicon camera for medical purposes. Proper lighting was important for two reasons. It provided the physicians with better color information; flesh tones could be interpreted more easily. And, it also provided better depth information; details could be more easily observed and interpreted. The physicians also found it useful to have certain colored objects included in the televised scene for the purposes of calibrating their judgmental processes regarding color information. Since the objects had relatively constant color characteristics, they could be used to establish a baseline for interpreting color data. Coast Guard vessels equipped with such a system could use it to obtain reliable diagnoses from shore-based physicians, thereby reducing the number of unnecessary medevacs. (The possibility of equipping merchant ships with these capabilities is a function of projected system costs and probable payback in savings associated with avoiding unnecessary medevacs.)

Holzer's system provided instrumentation for the telemetry of temperature, blood pressure, electroencephalography (EEG), electrocardiography (EKG), pulse rate, respiration rate, heart sounds, and electromyography. It provided the consultant physician with a loud speaker to receive voice communications; an audiophone headset to listen to heart sounds; a four-channel analog display for the reading of EMG, ECG, and EMG information, a chart recorder for obtaining permanent records of selected physiological variables; and a monitor for the reading of pulse and respiration rates. The author stated that this setup was sufficiently extensive to support diagnosis by specialists in the various medical fields. But, he added that making it even more elaborate could have been justified. He felt that a system with lesser capability would not have been cost-effective.

Such data could be transmitted, on-line, to a computer for storage, processing, and/or the generation of telecontrol signals; they could be transmitted to an expert cardiologist whose job it is to advise medical support personnel; they could be transmitted to the hospital that would receive the patient; and they could be transmitted to all of these.

Computers and telemedicine. Computers can perform rapid analysis of complex data and even generate decisions when programmed to do so. Schaffler deals with the computer-assisted evaluation of biotelemetric data.[4] Data can be transmitted directly to a computer, on-line, in real time. The ultimate accomplishment is to design a servomechanism that would generate output which would control some treatment modality at the patient's side and would respond to the changes in the physiological variable or variables determining the output of the servomechanism processor. The processing and output side of such a system are already available. J. Boysen and others,

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[4]K. Schaffler, "Computer-Assisted Evaluation of Biotelemetric Data Acquisition in Humans," Biotelemetry 5(1):13, 1978.

for example, describe a portable, programmable infusion system.[5] Such a system, combining computer-aided diagnosis and treatment control, could enable an EMT to maintain a situation involving many injured people (e.g., during disaster relief). Combined with a telecommunications link to a shore facility, this system would enable an EMT to administer treatment under counsel of a physician.

An example of the kind of cybernetic system referred to above can be of value. Certain types of ventricular arrhythmia are dangerous in cardiac patients. These are premature ventricular contractions (PVCs). Coronary-care units give antiarrhythmia drugs to suppress this activity when the frequency of its occurrence is high enough (as determined by experience). Electrocardiogram telemetry data can be obtained from a patient by equipment carried in emergency medical mobile units. These data can be transmitted to a computer located several miles away. This would prove invaluable for the "rolling emergency rooms" employed by the Coast Guard for disaster relief. Rimkus discusses the use of biotelemetry to bridge large distances in emergency patient monitoring.[6] The data can then be processed to determine the frequency of PVCs per unit time. The computer can be programmed to generate a signal that controls an infusion system at the patient's side. R. W. Freeland mentions the use of telecontrol for the radio-dispensing of drugs. The infusion system delivers an antiarrhythmia agent such as lidocaine at a rate determined by the frequency of PVCs per unit time.[7] The rate of infusion is some function of the frequency of PVCs per unit time. As PVC frequency rises, the computer generates output to increase the infusion rate of the antiarrhythmia drug. Thus, from data originating several miles away, a computer can generate a signal to control a treatment device several miles away. Such treatment, if started early enough, can prevent the ventricular fibrillation which frequently ensues when a high frequency of PVCs sets up a cincus rhythm in the conduction system of the heart. This situation is the ultimate achievement in telemedicine.

Technical competency and telemedicine. Despite increasing levels of automation, human factors will remain important. Electroencephalographic data cannot be transmitted if someone in the ambulance crew does not know how to connect leads to the patient to pick up the appropriate signal to be transmitted. Pulmonary wedge pressure cannot be transmitted unless one of the ambulance crew knows how to snake a Swan-ganz catheter through the right cubital vein, into the superior-vena cava, then into the right atrium, right ventricle, pulmonary artery, and finally into small pulmonary arterioles. The same is true for transmitting information about cardiac output. The

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[5] J. Boysen et al., "A Portable Programmable Infusion System," Biotelemetry 5(1):47, 1978.

[6] U. Rimkus, "Everyday Use of Biotelemetry To Bridge Large Distance in Emergency and Patient Monitoring," Biotelemetry 5(1):47, 1978

[7] R. W. Freeland, "Telecontrol by Simultaneous Transmission from Multiple Transmitter," Biotelemetry 5(1):16, 1978.

transmission of data depends on the abilities of the ambulance personnel to perform the technical operations needed to procure the data from the patient. And, if the data are transmitted to a physician in order to help him direct treatment activities of the ambulance personnel by telecommunications, the ambulance personnel must know how to carry out the physician's instructions. Therefore, those who staff the emergency mobile units of the future must be provided with a more comprehensive education, both theoretical and practical.

Education and telemedicine. The future is always grounded in the past and present. The future of telecommunications utilization in emergency medicine depends on the education of paraprofessionals in the present. It also depends on the education of physicians. Telecommunications systems such as radio, telephone, and closed circuit television make excellent audio and audiovisual teaching tools. So it is valuable to educate physicians and paramedical professionals about and with telecommunications methods. Davis describes how teleconference systems expand the possibilities in continuing education.[8] O'Connell discusses the use of communications satellite for continuing education in nutrition.[9]

Communications satellites and telemedicine. Communications satellites are playing an extremely important role in radio, telephone, and television communications. Herman Pfeiffer, the Director of Emergency Medical Services Communications for the New York State Department of Health, recommends the launching of a communications satellite that would be exclusively for use with emergency medical services communications, or one that would be used as a public safety satellite, including the functions of law enforcement, fire, emergency medical services, and civil defense communications. He presents several reasons why such a communications tool would be valuable. The increased transmission range and lower power requirements of a satellite based system result from the fact that the electromagnetic wave emitted by the transmitter is aimed up toward the satellite, thereby avoiding ground obstacles which would interfere with transmission. Access to out-of-area facilities is direct and immediate due to increased communication range. Fewer radio/telephone patches and switching functions are needed in such a system. Multiple consultations among several physicians in widely separated locations are possible without the need for elaborate switching gear and patching. The cost per unit of use is much less with satellite communications since the need to construct multiple radio base relay stations is eliminated. Finally, the cost of maintaining the system is probably lower than a comparable terrestrial system.[10]

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[8] D. L. Davis, "Teleconference Systems Expand C.E. Possibilities," AORN Journal 28(3):377-8, 380, September 1978.

[9] W. K. O'Connell, "Stardate I, Continuing Education via Communications Satellite," Journal of the American Dietetic Association 73(3):270-2, September 1978.

[10] Herman Pfeiffer, Director of Emergency Medical Services Communications, New York State Department of Health, Private Communications, 1979.

The value of satellite communications for providing health care to people in areas where there are few, if any, highly trained medical practitioners and health care facilities is illustrated in two projects. Foote discusses the contribution of satellite communications to rural health care in Alaska, and Fuchs deals with the attitudes of medical providers toward a telemedicine project on the Papago Reservation.[11,12]

Teleconsultation

Rural health care in Alaska is one example of the many benefits that can be obtained from the practice of telemedicine. The Maryland Emergency Medical Services Communication System is another. A third example is the use of telemedicine to improve the quality of care in the central care unit of a small hospital.

Grundy and others hypothesized that telemedicine could solve some of the problems associated with the scarcity and uneven geographic distribution of specialists in critical care medicine.[13] A two-way audiovisual connection enabled critical care specialists at a large university medical center to provide consulting services to patients in a small private hospital. The conclusions of the authors regarding the efficacy of the project was based on a 175-day trial period. They found that:

- Teleconsultation services were provided on a regular basis.
- Although current technology was adequate, it was also expensive.
- Services were generally acceptable to users and providers.
- Telemedicine had potential for being an excellent vehicle for staff and patient education.
- Use of telemedicine probably resulted in improved care to patients, and possibly contributed to reductions in morbidity and mortality of patients as well.

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[11]Dennis R. Foote, "Satellite Communication for Rural Health Care in Alaska," Journal of Communication 27(4):173-82, Autumn 1977.

[12]M. Fuchs, "Provider Attitudes Toward STARPAHC: A Telemedicine Project on the Papago Reservation," Medical Care 17(1):59-68, January 1979.

[13]Betty L. Grundy et al., "Telemedicine in Critical Core: An Experiment in Health Care Delivery," Journal of the American College of Emergency Physicians 6(10):439-44, October 1977.

- Audiovisual transmission provided a better medium for teleconsultations than telephone transmission.

- The relationship between the small hospital and the large university medical center grew stronger as a result of the telemedicine project.

The last two statements that they made in their paper are the key to establishing telemedicine as a major contributor to health care:

> Present problems of telemedicine in critical care stem less from inadequate technology than from inadequate ways of using available systems. Technical innovations can free us from limitations of time and space only when we develop innovative professional and administrative patterns of use (p. 444).

The contribution that telecommunications can make to the practice of medicine depends more upon whether and how professionals and administrators decide to employ its technology than upon the limitations that might be encountered in the applications of the technology. The potential exists for telecommunications science and technology to provide the components and systems that can bridge time and space restrictions in health care. The specific applicability to Coast Guard medicine is significant. The talents and experiences of the most highly trained medical experts can be employed in the most remote and out-of-the-way places to make a real impact on health care where it is not currently available or is less available than is desirable. Unnecessary deployment of Coast Guard resources--whose costs have been measured in lives as well as dollars--can be minimized. Telemedicine is one of the best ways we have to stretch the human and technological resources that are available to us.

4. COMPUTER APPLICATIONS

Computers have been used in the following medical applications:

- medical record-keeping
- clinical decision support systems
- computer-aided instruction
- monitoring of physiological functions of patients
- inventory and resource allocation

In each of these areas much work has been accomplished, but none of the systems are of such general utility that they can be easily implemented in in new settings. The ad hoc modifications necessary to effect transfers of this type can often be more formidable than the original development of the system.

Medical Record-Keeping

Many groups have tried to tackle the generic problem of "automation of the medical record" only to discover that there is no general agreement as to what functions are to be served by the medical record and the content and organization of the medical record. Arguments about format of an automated record quickly become moot when the more fundamental problem of defining the general structure and function of the record is unresolved. Three general types of medical records are likely to be important to the Coast Guard: 1) a general health profile on all personnel, including immunizations, dates of physical examinations with exception reporting of any abnormalities noted, indication of laboratory or X-ray determinations performed, vital signs, demographic data, etc.; 2) in-patient records of any illnesses, operations, or injuries requiring hospitalization; and 3) out-patient records (or encounters) for ambulatory visits to clinics, doctors' offices, etc. The first of these, and to a lesser extent the third, pertain to preventive health maintenance of the Coast Guard, while the second pertains to the care of the sick. In general, it is likely that preventive health maintenance will be the province of physician extenders (PAs, nurse practitioners, etc.), while the in-patient care will remain the concern of physicians.

With regard to the automation of health profiles, there are several prior efforts which could find useful application in the Coast Guard. For many years a number of physicians have utilized the "Cornell Medical Index,"[1] a 200-question self-administered survey questionnaire completed in 30-40

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[1]K. Brodman et al., "The Cornell Medical Index; An Adjunct to Medical Interview," J.A.M.A. 140:530, 1949.

minutes by new patients and aimed at pinpointing areas of prior health problems. Following this model, multiple groups have developed automated medical history systems, some self-administered, some using optically scanned forms, some using direct interaction of patients with computer terminals for data input.[2,3] Although ambitious and thoroughly studied and developed often at great expense, the automated history systems have for the most part not survived[4] to be routinely used in medical practice. At several community clinics in Houston, a computerized Health Illness Profile ("HIP") is used to capture in brief form the major active problems of each ambulatory patient and a few of the key abnormal findings. The Harvard-sponsored community health clinics also use an automated encounter form which is brief and has apparently survived because it does not require an unusual amount of physician effort to capture and retrieve basic encounter information about patients. Inasmuch as the Coast Guard will usually be dealing with a healthy population, a useful model might be the very large computerized patient registry developed in Stockholm, Sweden,[5] including in computer-retrievable form a few key demographic and health-related items pertaining to all members of a large countywide population.

Health records are currently maintained, in written form, by the Coast Guard unit to which each individual is attached. When the individual is transferred, his or her record is sent (with the individual) to the new duty station. Automated health records could enable the medical section of each unit to maintain on-line records at their central facility. Units without such facilities could be served by the nearest unit (e.g., large clinics). These data could be reviewed periodically and transferred via terminals to permanent records at headquarters. Small units could be served by remote terminals and hard-copy print-outs could be maintained in a written health record similar to today's practice.

A very fundamental issue, which may have great importance with regard to future automation of medical records, is the question of whether patients will ultimately have easy access to, and carry with them copies of, their own medical records. An effort which has met with modest success is the application of the "Medical Passport."[6] The medical profession has not been

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[2] W. V. Slack et al., "Medical Interviewing by Computer," The New Physician 19:143, 1970.

[3] W. V. Slack et al., "A Computer-Based Medical History System," New England Journal of Medicine 274:194, 1966.

[4] S. R. Yarnall et al., "Acquisition of the Patient Data Base; A review of Design Approaches, Performance, and Cost of 55 Different Systems," Medical Computer Services Association, Seattle, Washington, April 1971.

[5] S. Abrahamsson et al., "Danderyd Hospital Computer System, II: Total Regional System for Medical Care," Computers and Biomedical Research 3:30, 1970.

[6] C. D. Forkner, "Record of Medical History," Arch. Int. Med. 106:22, 1960.

overly receptive to this notion because of concern about having patients and other doctors able to read at will and critique each doctor's notes about the patients.[7] If, however, current legal trends continue with respect to freedom of access to confidential information, it is likely that patients will one day have free access to their own records, and then the transmission of medical records by patients moving from place to place will become usual and customary. This could conceivably lead to decisions against providing large computerized data banks in which each patient's confidential medical records could be potentially retrieved by individuals without appropriate justification for accessing the information. Perhaps the safest way to keep a patient's records safe from inappropriate access would be a system in which the patient is responsible for carrying about with him his own medical records. Some computer systems today are subject to severe constraints due to the need to protect confidential information from unauthorized access; for example, an automated pharmacy system operating in a VA hospital had to be dismantled and significantly redesigned because of federal regulations against transmission of digitized data over telephone lines which would allow decoding of patient names at a remote computer receiving the transmitted signals. If decisions are made to have a large computerized information bank concerning the health status of a large group of Coast Guard personnel, a very close look should be first taken concerning the safeguarding of confidential data and the federal regulations already in place constraining the use of computerized information banks.

A rather important practical principle, which has been often ignored to the great detriment of medical data base systems (studied extensively at Duke University in relation to their well-known and functioning cardiovascular data bank), is that no item should be collected and entered into computer storage unless a specific use for that information has been planned and an individual or group of individuals have been identified who have any interest in and a commitment to utilize that item of information once it is in computer-accessible form. Unless this principle is followed, items of information will be collected with totally unacceptable error rates in the data, and the resulting information will be less than useless if a potential user appears at a later date with a need for the stored item of information. Obedience to this principle forces data bank developers to be conservative in terms of the size of data bases and the use of computer storage space and also to plan carefully for the future use of developed data banks. The resulting systems are much more likely to be used and to be cost-effective once they reach an operational stage.

Several relevant approaches to automated medical record-keeping are in operation. The PROMIS system, developed as a computerized version of Dr. Lawrence Weed's problem-oriented medical record system, is a well-known

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[7] B. N. Shenkin and D. C. Warner, "Giving the Patient His Medical Record: A Proposal To Improve the System," New England Journal of Medicine 289:688, 1973.

and commercially available system.[8] Despite some enthusiasm by many of the more recently trained physicians, the majority of medical professionals have not adopted this concept, while those that do use it tend to use only portions of the system suited to their own individual record-keeping styles and personal preferences.

Another type of structure is utilized in TOD (Time-Oriented Data system),[9] a medical information storage and retrieval system developed at Stanford University by Fries and co-workers. In that system, patient information is keyed to the variable, time (of occurrence or of data collection), which variable is characteristically accounted for either poorly or not at all in most other medical information processing systems.

A third system, MGH Utility Multi-Programming System (MUMPS),[10] has a number of advocates in a wide variety of different types of medically related environments; this system was developed at the Massachusetts General Hospital and is not used in many medical institutions. Although often thought to be a medical record system, MUMPS is more akin to a computer language that an appropriately trained computer programmer can use in the design of medical programs.

Probably the most elaborate automated record system in current use today is the system implemented by the Technicon Corporation at the El Camino Hospital in Long Beach, California, at Fort Monmouth, New Jersey, and at the Clinical Center of the National Institutes of Health. This system utilizes many terminals (greater than 160 at the Clinical Center) and costs between $1 million and $2 million for annual maintenance. The Technicon system was designed for manipulation of data on hospitalized patients. Its use for health maintenance of a population of healthy individuals, such as Coast Guard personnel, has not been tested.

The Generalized Medical Information System for Community Health (GEMISCH)[11] was developed at Duke University; it was built around data entry from self-administered, optically scanned questionnaires, but is now fully operational using a variety of types of interactive data entry techniques. Since the system was designed for information collection in a healthy population, this system deserves consideration as a reasonable model for a Coast Guard automated medical record-keeping system.

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[8] L. L. Weed, Medical Records, Medical Education, and Patient Care, Case Western Reserve University Press, Cleveland, Ohio, 1969.

[9] J. F. Fries, "Time-Oriented Patient Records and a Computer Data Bank," J.A.M.A. 222:1536, 1972.

[10] G. O. Barnett et al., "Quality Assurance through Automated Monitoring and Concurrent Feedback Using a Computer-Based Medical Information System," Medical Care 16, November 1978.

[11] S. C. Lloyd et al., A Generalized Medical Information System (GEMISCH) for Practicing Physicians, National Conference of the ACM Proceedings, August 1971, pp. 684ff.

The CLINFO system,[12] designed for NIH by the Rand Corporation and now being marketed by Bolt, Baranek and Newman, is currently in use by a number of clinical investigators at Baylor College of Medicine (Houston), Vanderbilt University (Nashville), the University of Washington (Seattle), Johns Hopkins University (Baltimore), and will soon also be available at Duke, Yale, the Mayo Clinic, the Peter Bent Brigham Hospital and other clinical research sites within the next three years. It is a minicomputer-based system for the storage, retrieval, data management, and analysis of data from modest-sized sets of patients (e.g., less than 5000 patients per study). It has been carefully designed from the "human engineering" standpoint to enhance the man-machine interface between physician-user and computer. The system is being actively used by a number of doctors whose prior exposure to computer systems was disappointing. It was not designed to be an automated record-keeping system, but it does have some features (especially ease of data retrieval and analysis) which make it an attractive model. The CLINFO system incorporates the time oriented data storage developed for the TOD system at Stanford.[13]

Another computerized data management system developed for biomedical applications by the NIH in collaboration with Bolt, Baranek and Newman is the PROPHET system.[14] Like CLINFO, it has certain attractive features in terms of ease of retrieval and analysis of large sets of data, but it again was not designed specifically to become the basis for an automated medical record keeping system.

Each of the systems mentioned in the preceding pages is a mature system that has found groups of real-world users. Each of those systems was initially developed at a cost between a few hundred thousand and a few million dollars and took several years to implement. Nevertheless, despite the large investment of resources in these "automated medical record" systems, there is no agreement as to what strategy should be followed for the future automation of medical records by large organizations not currently committed to one or another of these developmental approaches. There is a significant need for a comprehensive comparative study of the characteristics of existing automated medical record-keeping systems. From such a study and an analysis of the information-processing needs of the Coast Guard, a reasonable plan could be generated for the introduction of an automated medical record system for the Coast Guard. Presumably, such a plan would take advantage of parallel development activities being carried out by the Army, Navy, and Air Force medical establishments.

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[12] G. F. Groner et al., "An Interactive Data Management and Analysis System for Clinical Investigators," J. Lab. and Clin. Med. 92:325, 1978.

[13] Fries, "Time-Oriented Patient Records and a Computer Data Bank," 222:1536.

[14] P. A. Castleman et al., "The Implementation of the PROPHET System," AFIPS Conference Proceedings, vol. 43, 1974, pp. 457ff.

Automated medical record systems usually contain information about individual patients or groups of patients. At a higher level of generality, one can consider the aggregate bodies of information required for operation of an entire hospital. At this level, information is included which does not usually appear in a patient's medical record such as bed census, bed allocations, inventory of hospital equipment, pharmacy supplies, hospital diet information, patient billing information, payroll, etc. Such "hospital information systems" have been in existence since about 1961, when IBM announced the first commercially available total hospital system, then known by the acronym "HIS" (Hospital Information System); today, a more mature offering by IBM is known as "MIS" (Medical Information System). Because of the enormous expense required to implement a computerized hospital information system, the widespread diffusion of these systems has been limited to date. A number of computerized hospital information systems of varying size, complexity, and expense are available today, however. The Technicon enterprise at El Camino Hospital is probably the most well known of these developments. It can be predicted that over the next two decades there will be a gradual increase in the number and size of hospital information systems throughout the country, limited almost certainly by availability of funds. Growth and development of this type of computer application have been steady over the past two decades, but at a much slower rate than was initially projected because of the enormous development costs. Since the Coast Guard's mission is more closely tied to health maintenance than to the care of hospitalized patients, the development by the Coast Guard of hospital information systems modeled after the El Camino system would probably be of lower priority than the development of a usable, automated medical record system.

Clinical Decision Support Systems

In the early 1960s IBM invested over a million dollars in the design of an automated "clinical decision support system" (CDSS),[15] in which medical history, physical examination and laboratory data were to be entered interactively into computer storage and the computer was to display a list of the current diagnostic possibilities ranked according to statistical probability of being the correct diagnosis. Each piece of added information might result in a substantial revision of the ranked list of probable diagnoses. Although the early IBM development led to much new information about medical computer systems and resulted in an operational system of hardware and software, CDSS never reached the stage of successful operation in the real world because of inadequate understanding of the magnitude of the task of obtaining sufficient medical input into the programs to make them practically usable. In order to bring the system into useful operation, it was estimated that several hundred thousand man-hours of M.D. input would be required, and such a commitment of medical talent and resources was not available for that purpose. However, the concept that the computer could be used to assist the physician in arriving at clinical decisions was a valid one, which has surfaced repeatedly in the past 15 years in a variety of ways. Undoubtedly, this will ultimately become one of the most important uses for computers in medicine. Currently, two different

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[15] H. Fallon, G. Goertzel et al., "A Primer for Writing Medical Data Base for the Clinical Decision Support System," Progress in Brain Research 33:155, 1970.

and apparently unrelated lines of research activity may be converging to produce computerized clinical decisions systems of the next 25 years: 1) development of clinical algorithms for implementation by supervised physician extenders (P.A.s, medical corpsmen, nurse practitioners, etc.), and 2) studies under the general heading of "medical artificial intelligence."

Algorithms. Starting in the 1960s at Fort Belvoir in Virginia and in the 1970s at Fort Sam Houston in San Antonio (the "AMOS" project),[16] as well as at several of the larger teaching medical centers, algorithms have been designed to permit a non-M.D. to examine, assess, and treat certain well-defined and frequently encountered clinical problems such as sore throat, urinary tract infection, and headache. By following a carefully predefined set of branching instructions, it is reasonable for many, but not all, such cases to be seen and managed without the direct intervention of physicians. Figure 4-1 provides an example of such an algorithm. The algorithms themselves lead the physician-extenders to refer any problem cases for further evaluation by physicians. It has been found that these clinical algorithms are of enormous value in training paramedical assistants in quality control of clinical management of ambulatory patients, as well as in making it possible for a single physician assisted by one or more extenders to care efficiently for a large number of ambulatory patients. To date, most of the clinical algorithm activities have not made extensive use of the computer, except perhaps in retrospective analysis of the adherence by a group of physician-extenders to the algorithms. As more and more algorithms are developed, tested, and refined, it can be anticipated that some of them will be automated and utilized as components of a gradually emerging "clinical decision support system." The importance of the current studies, however, does not bear so much upon development of computer applications as upon the development of formal branching decision logic, which begins to capture in easily understandable and verifiable terms the decision processes which a physician seems to go through (although usually in a less consistent and orderly fashion) in his management of certain clinical problems. Only after such decision trees have been documented and validated does it become feasible to program such decision logic for use in automated clinical decisions.

Artificial intelligence. At Stanford University (under Drs. Lederberg and Feigenbaum), M.I.T., Tuffs Medical School, University of Pittsburgh, Rutgers University and elsewhere, there are groups actively modeling the way physicians make diagnostic and/or therapeutic decisions. Generically, this activity is referred to as "artificial intelligence" or "A.I." in medicine. The problem of arriving at medical diagnosis by computer (first articulated in the Journal of the American Medical Association by Dr. Homer Warner in 1961) has been subsumed under this general heading. Compared to other medical computing research activities, the A.I. studies are aimed more at future payoff than present application, the assumption being that in the future the computer will be increasingly used to assist in decisions traditionally thought to require human cognitive processes. Therefore, in

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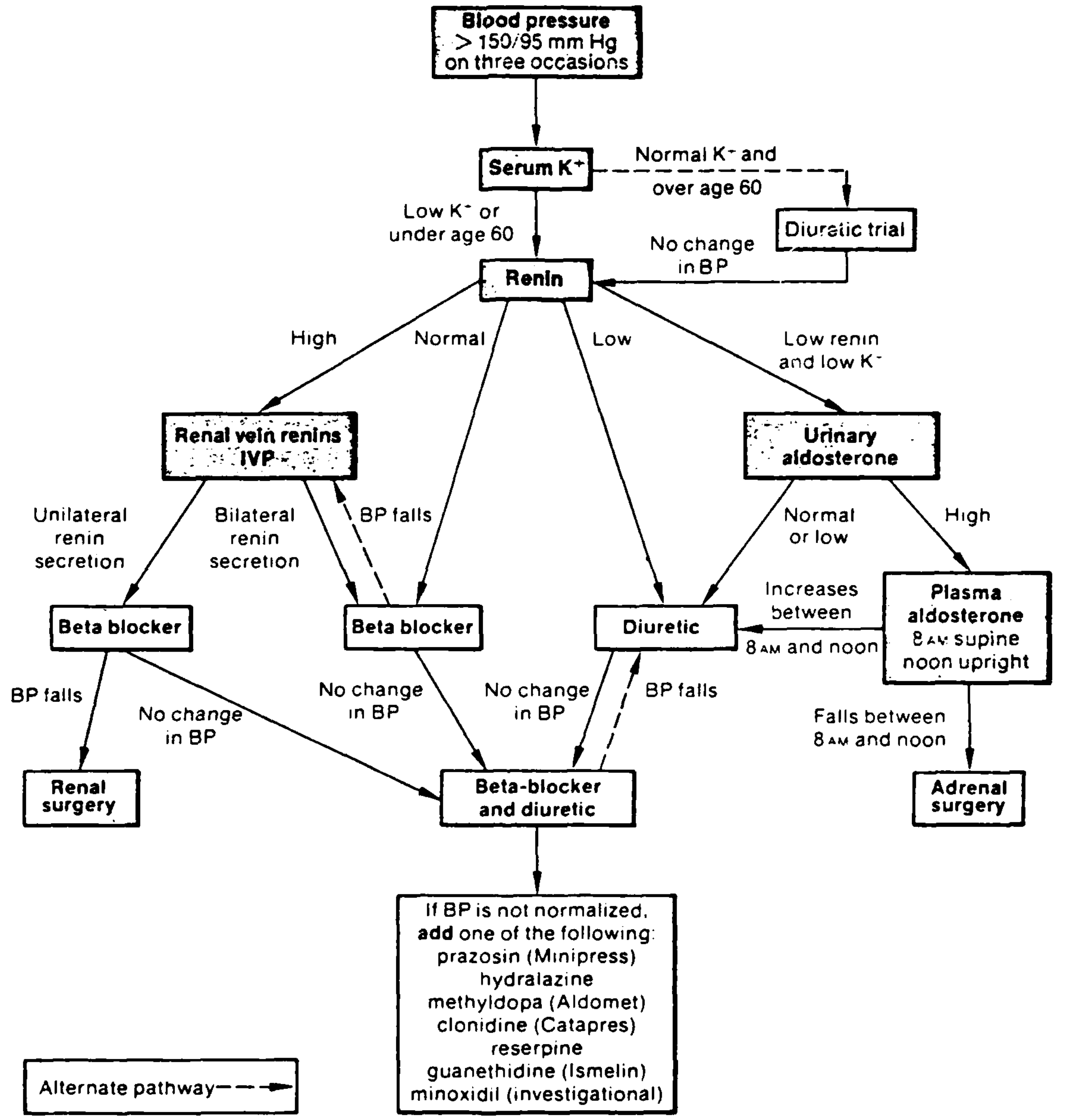
[16] B. W. Wolcott et al., "The Use of In-Barracks Screeners To Improve Military Sick Call," Military Medicine, Vol. 144, February 1979.



Normokalemic patients over age 60 may be first tried on diuretics because of the higher prevalence of low-renin hypertension in this group. Low-renin patients with hypokalemia (serum K+<3.5) are evaluated for adrenocortical disease and high-renin patients for renovascular disease. Surgically noncurable patients return to the basic treatment program. Normal- and high-renin patients are started on a beta blocker and low-renin patients on a diuretic. If either course is only partially corrective, the two regimens are combined. This approach will normalize blood pressure in some 85% of patients. For the remaining 15%, other, less palatable drugs are superimposed on a traditional trial-and-error basis.

Adapted from Laragh J. Essential hypertension: New concepts in diagnosis and treatment. *Compr Ther* 4:10-17 1978

SOURCE: J. H. Laragh, M.D., "Hypertension," Drug Therapy, Vol. 10, No. 1.

FIGURE 4-1. A FLOW SHEET FOR DIAGNOSING AND TREATING HYPERTENSION.

these studies the computer is programmed to mimic, whenever possible, human cognitive processes. Some of the programs generated by the medical A.I. researchers are already either at the state of practical application or are rapidly approaching it: 1) the MYCIN program, developed at Stanford (Shortliffe), assists the physician in prescribing an appropriate combination of antibiotics for patients with evident infections prior to the availability of reports of bacterial cultures; 2) programs developed at the University of Southern California (Jeliffe), at Berkeley (Scheiner), and at M.I.T. (Pauker et al.) address the question of monitoring the dosage of the important and potentially toxic cardiac drug, digitalis; 3) at Rutgers (Amarel et al.) complex algorithms have been developed for the management of patients with glaucoma; 4) at Pittsburgh (Myers et al.) a very extensive internal medicine diagnostic program ("INTERNIST") has reached the stage where the computer can competently diagnose the great majority of complex internal medical conditions. Pauker and Gorry at M.I.T. and Baylor have published interesting analyses of the cognitive processes whereby a physician brings from long- and short-term, memory-stored information to arrive at medical decisions.[17]

It seems reasonable to project that in a few years the concept of computerized clinical decision support systems will become a reality in a number of medical settings, combining concepts initiated in the earlier IBM studies of CDSS, the generation of clinical algorithms for use by physician extenders, and the current studies of medical "artificial intelligence." In the case of the Coast Guard, it would seem appropriate that serious consideration should be given to identifying and flow-charting certain key problem areas (e.g., search and rescue missions, early management of drowning victims, etc.), where decisions of importance to the U.S. Coast Guard medical establishment are made repetitively. When such flowcharts (i.e., algorithms) have been tested and validated, they can later be incorporated in whatever automated medical computer systems are available in the Coast Guard medical environment. It is likely that much of the routine "sick call" for the Coast Guard, consisting of upper respiratory infections, low back pain, etc., will be managed by physician-extenders with the help of algorithms such as those used by the Army in the AMOS project referred to above. The hope for computers in medicine, first articulated in about 1960, was that with the aid of physician-extenders and video-terminals communicating with remotely situated computers, a small number of physicians could care more effectively for a much larger population of patients, both sick and healthy, than could a physician without this type of help. It now seems entirely likely that this hope may be realized within the next two decades.

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[17] S. G. Pauker et al., "Towards the Simulation of Clinical Cognition: Taking a Present Illness by Computer," American Journal of Medicine 60:981, 1976.

Computer-Aided Instruction

For over a decade much work has gone into the development of computerized self-instructional "packages" whereby a student can sit at a computer terminal and learn the material for a given course at his own pace and without the need for much direct faculty supervision. At Ohio State Medical School a rather large investment has been made in computer-aided instruction ("C.A.I.") to be used in medical school courses. Because of the enormous amount of faculty time required to design a computer-aided course package, the impact of this type of educational technology has been limited. The U.S. Naval Academy at Annapolis had a rather substantial program of C.A.I. instruction in several courses, including physics, Russian, and naval science, but the expense of maintaining this effort was large and the program was ultimately abandoned. There is some enthusiasm, however, for at least two rather useful C.A.I. packages for the training of medical and paramedical personnel: 1) a course in advanced cardiopulmonary resuscitation ("CPR"), developed originally at the Massachusetts General Hospital; and 2) a program entitled CASE, in which complex medical cases are simulated in the computer and the user is asked to work up and manage the patient by making interactive responses to computer-generated questions appearing on a video-terminal. The computer criticizes the management of the patient with respect to the user's choice of diagnostic or therapeutic measures, time required to bring about effective treatment, and the relative cost of the proposed management options. There may already be settings within the U.S. Coast Guard medical environment where the CPR program could be usefully introduced for the training of professional and paraprofessional personnel, who may need to develop competence in the emergency handling of cardiopulmonary emergencies. It is likely that there are a number of recurring problems where C.A.I. instruction of Coast Guard personnel would be helpful (management of drowning cases, smoke inhalation, etc.). Such packages might usefully be combined with visual displays (slides, videocassettes). Such C.A.I. packages are usually not cost-effective in their own right as the single justification for the acquisition of an expensive computer system, but C.A.I. packages can be very effectively utilized if there exists an appropriate computer system in the environment which can support this type of application. Quite possibly C.A.I. will constitute one of the most important types of computer usage for the U.S. Coast Guard medical establishment of the future.

Physiological Monitoring by Computers

Computer "patient monitoring" is another important area in which a great deal of effort has been expended. This effort has focused on providing automated alerting mechanisms to physicians and nurses when abnormal signals are detected in monitored physiological functions; these include, for example, significant rhythm disturbances on electrocardiograms; and abnormalities in pressure tracings of the systemic, the central venous or pulmonary arterial circulation. At some sites (especially the Latter-Day Saints Hospital in Salt Lake City, the University of Alabama Medical Center, Duke University, Washington University in St. Louis, and the Pacific Medical Center in San Francisco), such monitoring systems are highly effective. Beyond simple monitors are more complex systems, for example, for the computer diagnosis of the twelve-lead electrocardiogram, but these programs are large and usually are run on dedicated computers utilized for no other function. These EKG diagnostic programs, originally envisioned as a subset of the patient monitoring problem, are currently running in electrocardiographic departments on computers which are completely independent of other physiological monitoring functions. The principal use of the EKG in patient-monitoring environments is for the detection and counting of premature ventricular contractions, an important function in coronary care units.

In work with the astronauts, remote monitoring of pulse rate and of several leads from the electroencephalogram have been studied extensively. Remote monitoring of the pulse rate under conditions of stress can be inexpensive. A major use of electroencephalographic monitoring has been in the monitoring of the stages of sleep. Again, if the U.S. Coast Guard has built-in requirements for exposure of personnel to situations in which pulse or sleep monitoring would be helpful, NASA should be consulted on the experience.

In summary, although much work has been done with regard to computer monitoring of certain physiologic parameters, the need for automated physiological monitoring by the Coast Guard may be considerably less than the need for implementation of other types of medical computer applications.

Inventory and Resource Allocation

The use of computer systems is rather well developed in industry and many government organizations. In medicine there are similar pharmacy inventory systems (either traditional or unit dose systems) which keep track of inventory of medications on hand, of medications and dosages prescribed for individual patients, medication charges, etc. Drug-drug and drug-laboratory-test interaction programs exist, but are not well debugged or in wide usage. In New Orleans (Balintfy), complex hospital dietetic programs have been developed in which current market prices for food stuffs, patient diet orders, and patient food preferences can be combined as inputs to the programs. Outputs consist of foodstuffs to be ordered by the hospital on the open market and of meals to be served to the individual hospital patients.

In a number of operations research installations, computers are being utilized for the design of models of varying complexity to assist in decisions about resource allocations. Comprehensive models pertaining directly to the allocation of health-related facilities have not been used very often. One outstanding exception was the development at the medical school of the University of Toronto (Dr. Richard Wilson et al.) of an elaborate model of the commitment of faculty and student time and effort for an entire medical school, the use of which resulted in very critical administrative decisions relating to the future development of that medical educational institution. As administrators become increasingly aware of the major contributions which often result from the development of idealized models of system behavior, it is anticipated that more and more models of health resources will be developed. If not under development at this time, there may be an important advantage for the Coast Guard to begin the design of a mathematical model of the U.S. Coast Guard health-related resource allocation system. Objectives of developing such a model might include: optimal distribution of health professionals and paraprofessionals in the Coast Guard medical system; determination of the need for future recruitment and training of doctors, nurses, and P.A.s; determination of the effects of various proposed changes in Coast Guard personnel deployment, activities, etc. Such a model would probably highlight the quantitative aspects of the numbers of people served by different components of the Coast Guard health maintenance system and hence motivate decisions concerning the needs for future technological and personnel support, with or without computer systems.

Figure 4-2 presents the reporting form currently used in SAR-related incidents. It includes descriptions of the characteristics of the SAR missions but does not include space for entry of information about the medical factors involved. The incident summary information is currently entered into a CG automated retrieval system and recovery of these data are straightforward. On the other hand, medical data pertinent to emergency missions are not well organized, primarily based on written reports, and statistical reconstruction of these data are difficult. (The data on nature of shipboard accidents in Chapter 7 was, for example, compiled by Coast Guard personnel by tracking written reports.)

If medical data were available on the incident summary, or similar data systems were introduced for medical purposes, statistical and epidemiological analysis and the policies flowing from them could be enhanced.

General Comments

Fifteen or twenty years ago most computer advocates described future computer systems and capabilities which were far more elaborate and dramatic than most of those seen in operation today. Overpromising and the concomitant disappointment were probably inevitable. It is now realized that there are a great many human-engineering problems not immediately visualized by computer technologists and designers, which require careful and painstaking study and advance planning before a computer application can be designed, programmed, and successfully introduced into a real-world environment. The time and resource expenditure for this type of activity can be great. Decisionmakers, who have in the past balked at the high cost of computer hardware, are sometimes persuaded today to purchase computer equipment of much greater capability at a much lower cost, only to discover to their dismay that today the main cost of developing viable computer systems is not to be found in the computer equipment itself, but in the high personnel costs for preliminary planning, systems analysis, and careful consideration of human engineering factors often related to the so-called "man-machine interface." In health-related applications, there is unfortunately no substitute for the required study and discussions with the proposed end-users of the systems, especially physicians, nurses, and paramedics. Such discussions must occur before the initial designs are established and should continue on an interactive basis throughout the development effort.

SAR INCIDENT SUMMARY

DS	OPFAC (A01)	Unit Case No. (A02)	Multi-Unit Case No. (A03)	Date of Coast Guard Notification (B01) M / D / Y / Time

CASE DATA SECTION

Time from Occurance (B02)	INITIAL Severity (B09)	Date / Time of Location (B16)
Means of Notification (B03)	ACTUAL Severity (B10)	Lives Lost (B17) BEFORE / AFTER
Nature of Distress (B04)	Cause of Distress (B11)	Lives Saved (B18)
Distance Offshore (B05)	Owner (B12)	Persons otherwise Assisted (B19)
Latitude (B06)	Usage (B13)	Value of Property Lost (B20) Value / 100 i.e. 1500 = 15; 250.000 = 2.500
Longitude (B07)	Propulsion (B14)	Value of Property Assisted (B21) Value / 100 i.e. 1500 = 15; 250.000 = 2.500
Method of Locating (B08)	Length (B15)	

SAMPLE

SORTIE SUMMARY

SORTIE	Assisting Resource Type (C 04)	Date / Time Underway (C 06)	Distance To Scene or Search Area (C 07)	Total Time On Search (C 08)	Date / Time Assisting Resource ALONGSIDE (C 09)	Total Time On Scene (C10)	Total Time On Sortie (C 11)	Sea State (feet) (C 12)	Wind (knots) (C 13)	Visibility (C 14)	ASSISTANCE RENDERED BY CG (C 15) TO: Personnel	Property
1												
2												
3												
4												
5												
6												
7												

REMARKS

NAME OF DISTRESSED UNIT	REGISTRATION NO. (optional)	NAME/ADDRESS OF OWNER/OPERATOR

A - 1

(Reverse Blank)

FIGURE 4-2. SAR REPORTING FORM.

The future use of computers by the health establishment will certainly benefit from a number of trends that are apparent today.

- The trend of the last decade of decreasing hardware costs and increasing capacity will continue for at least another two decades (See Figures 4-3 and 4-4).

- The decisionmakers of 10-20 years from now will have come through an educational system in which the usefulness of computer technology is taken for granted. Many of today's high school students have taken computer programming courses. Computers will not be mysterious tools for mathematicians and engineers only. Hence, when these young people are required to decide among various technological options, they will not first need to be persuaded that computers are potentially useful in a variety of settings. Consequently, decisions in favor of new computer systems will be made with increasing frequency over the next 20 years as this group of young people enter the ranks of the decisionmakers.

- The current confrontation between those who see great advantages in larger and more comprehensive computerized information banks to support health-care management decisions and those who are trying to guard against infringement upon rights of privacy and protection of confidential data will continue. Privacy considerations, even though they often seem trivial in any given application, must be carefully considered in the design of any new computer system for storage and retrieval of U.S. Coast Guard health data.

- Unless there exists a very detailed and comprehensive analysis of the information transfers inherent in the current and proposed U.S. Coast Guard health maintenance systems, such a study should be initiated. This type of study can easily take 2-5 years to complete and requires considerable special expertise to carry out. Until this is done, it is not likely that any sensible answers can be given to global questions, such as, "What will be the needs of the U.S. Coast Guard health establishment for computer hardware and software systems over the next several years?" Sometimes such a study will include the design and building of a mathematical model to represent the significant information transfers and resource allocations in order to assist in characterization of the existing or proposed system. The input of experts trained in operations research techniques can be very helpful in this type of planning activity.

- It can be anticipated that there will be a gradual increase in the use by the U.S. Coast Guard medical and paramedical staff of computers in the support of clinical decisions. This type of application will probably occur after problem areas specific to the health needs of the U.S. Coast Guard

[1] By 1985, ICs with complexities of one million devices per chip will be possible. Microcomputers handling 32-bit operations are one manifestation.

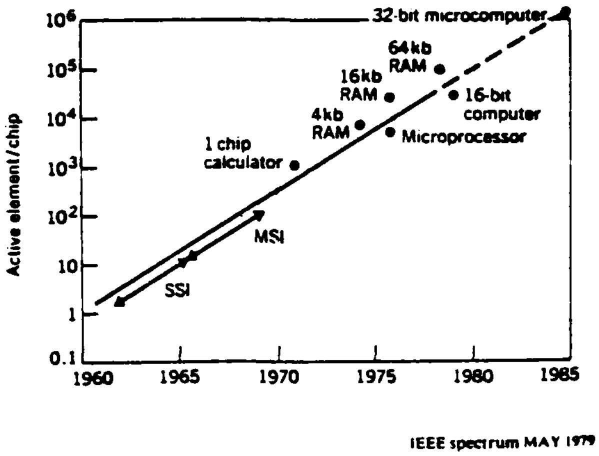

FIGURE 4-3. INCREASED COMPUTER CAPACITY.

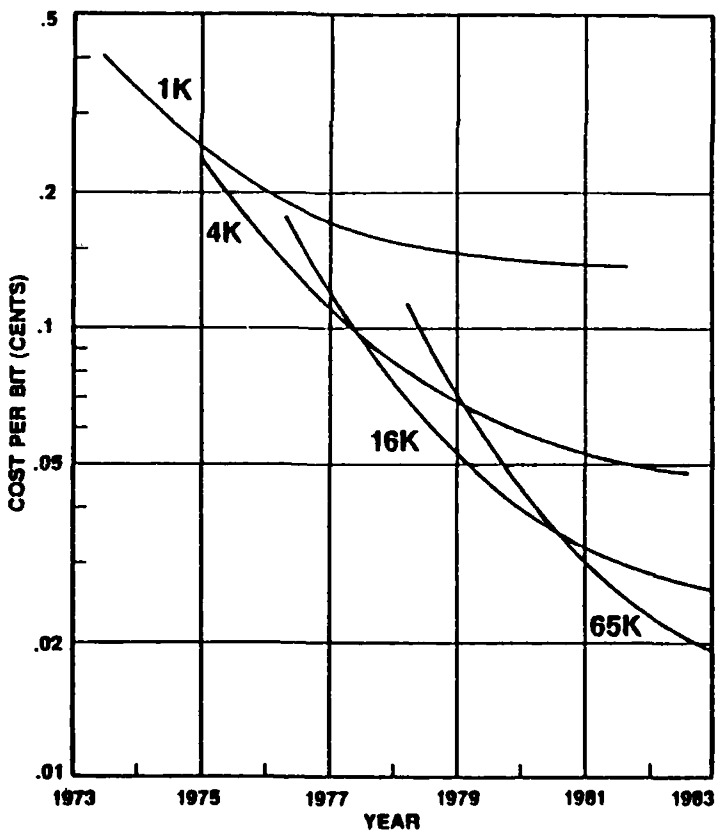

FIGURE 4-4. SEMICONDUCTOR MEMORY COST PER BIT.

have been pinpointed, and algorithms for handling such problems have been designed and validated. This type of activity will almost certainly occur with increasing frequency, as the results of ongoing studies of "medical artificial intelligence" become more widely known.

- Computer-aided instruction packages, such as that instructing individuals in advanced emergency life-support, will probably find increasing uses in the training of Coast Guard health personnel.

- Computer control of pharmacy inventory and medical supplies will become increasingly utilized in order to detect areas of significant waste of supplies, critical shortages, etc.

- During the past few years, considerable work has been done by different branches of the U.S. Government on the use of computers in the clinical management of sick and healthy patients. The Public Health Service, the V.A. Hospital system, and the medical establishments of the Army, Navy, and Air Force have devoted significant resources to this type of development. There is a wealth of experience which could be useful in the development of any similar large-scale medical computer effort within the U.S. Coast Guard.

5. MOBILE HEALTH CARE DELIVERY SYSTEM

Introduction

Medical practitioners have long recognized the need to bring medical care to remote areas and to people who for geographic, social, or economic reasons are hard to reach. Not only has communications technology had a great impact on extending health care services (Chapter 4) but improved transportation as well has been responsible for extending the reach of medical services. Today there are specialized mobile units to provide transportation for cardiac patients, obstetrical patients, neonates, burn victims, and patients in respiratory distress. Mobile health care units are not limited to emergency medicine but are also used to bring appropriate facilities to patients in need of general physical examinations, vaccinations, X rays, dental treatments, and eye examinations. Screening for hypertension, tuberculosis, emphysema, certain types of cancer, and sickle-cell anemia has been brought to the public via mobile facilities, although mobility is not usually an overriding consideration in these activities.

For the Coast Guard, there are three types of mobile laboratories and health care units of importance: first, the future equivalent of the ambulance or emergency helicopter, designed to perform rapid diagnostics, patient stabilization and transportation to longer term care facilities; second, mobile health care units which will have to provide longer periods of care and support at least some therapeutic procedures, such units might be employed in ship sick bays; third, in the future the Coast Guard might be called upon to provide medical care in the event of emergency situations in which numbers of people are affected. In this case, the mobile units might be required to provide more extensive diagnostic and initial patient stabilization support as well as laboratory and mobile hospital facilities. In all of these areas, important developments are occurring in equipment miniaturization, noninvasive monitory techniques, and delivery speed.

Current Status

Manufacturers of medical equipment have not been slow to recognize the need for portability; it is needed for in-hospital use as well as for emergency vehicles. The general trend toward computerization and miniaturization in instrumentation has helped manufacturers to develop portable equipment for use both in hospitals and patient transfer vehicles. A good example of this technology is the mobile life-support system used by Hermann Hospital in Houston, Texas. It provides pulsatile membrane oxygenation, balloon augmentation, respirator or hand bagging, endotracheal suction, external defibrillation, ECG and blood pressure monitoring, external cardiac massage, and pacing via a transvenous pacemaker. It also has pharmacologic components. The unit is used both in the hospital and in transit.

One patient was kept on cardiopulmonary bypass during a 200-mile helicopter and ambulance trip and straight through the performance of arteriography at the hospital. The system was designed for use in Bell Huey or larger helicopters but is being redesigned to fit smaller helicopters.[1]

Not much of the equipment in emergency vehicles is diagnostic. The reasons for this are space limitations, the orientation toward resuscitation and stabilization, and the lack of trained personnel to perform invasive procedures or to make sophisticated interpretations of diagnostic data. Electrocardiography and the Doppler flowmeter are exceptions to this general rule. The latter was developed because of the need during cardiopulmonary resuscitation for a rapidly applicable noninvasive means of monitoring instantaneous blood flow. Cardiopulmonary resuscitation produces a variability in blood flow that is not reliably indicated by systolic pressure pulses and there is a lag time before clinical signs begin to reflect inadequacy of perfusion.[2] With the use of a Doppler flowmeter a resuscitation team has greater knowledge of the patient's hemodynamic status. This device permits emergency personnel to alter cardiac massage techniques they had previously been considered accurate in order to produce maximal blood flow sounds.[3]

The Intermountain Respiratory Intensive Care Unit located at the LDS Hospital in Salt Lake City is responsible for providing air transportation for patients with acute respiratory failure. Patients are stabilized before transport. The ventilatory pattern (minute ventilation, tidal volume, and respiratory rate) is monitored and adjusted until satisfactory blood gas levels are obtained. The patient is then transported with intravenous, nasogastric, urinary, endotracheal, and often chest tubes in place. Vital signs, ventilation checks and medications are recorded en route every 10-30 minutes. Before arrival, the transport team radios the ambulance team and hospital as to the equipment, diagnostic tests, and personnel that will be needed. Thus, diagnostic activity is minimal during transport but relied upon heavily at both ends of the trip.[4] The team does not believe that blood gas analyzing equipment need be available during transport. If the patient's condition has been properly stabilized, all that is usually required

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[1]A. J. Lande et al., "Mobile Profound Life Support," Transactions of the American Society for Artificial Organs," Vol. 23 (1977), pp 736-737.

[2]Charles F. V. Grunau, "Doppler Ultrasound Monitoring of System Blood Flow During CPR," JACEP: Journal of the American College of Emergency Physicians, Vol. 7, No. 5 (May 1978), p. 180.

[3]Ibid., p. 182.

[4]Keith W. Harless et al., "Civilian Ground and Air Transport of Adults with Acute Respiratory Failure," Journal of the American Medical Association, Vol. 240, No. 4 (July 28, 1978), p. 363.

is frequent monitoring of vital signs and ventilatory pattern and minor adjustments of intravenous infusion rates.[5]

The Intermountain Respiratory Intensive Care Unit performs patient transfer under fairly controlled circumstances, i.e., from one clinic or hospital to another. Emergency teams that are picking up patients at the scene of an accident or collapse may feel differently about the diagnostic support needed for their activities. Blood gas determinations are an important indicator of shock. Metabolic acidosis has been considered to be the classic acid-base abnormality in shock. However, early shock is characterized by a respiratory alkalosis and occasionally by a metabolic alkalosis due to the tendency of patients with trauma and shock to hyperventilate. The blood gases of a patient going into shock generally show a low pCO_2, a normal bicarbonate level and an elevated pH. If combined metabolic and respiratory acidosis develops, chances for survival are very poor even if blood pH can be restored to normal.[6] In cardiac arrest situations, early and frequent measuring of blood gases must be done to assure adequacy of treatment. Ventilation does not always correct the underlying acidemia, and adequate amounts of sodium bicarbonate must be administered to convert the heart effectively. The need for and adequacy of this treatment can only be known by frequent analysis of blood pH.[7]

Shock is probably the condition most common to various emergency medical situations and the one for which mobile laboratory equipment would be most helpful. The understanding of the physiopathology of shock has increased tremendously in recent years, but is still incomplete and, in some instances, probably erroneous.[8] There are increasing numbers of patients who have been in severe shock and who have been successfully treated.

The monitoring of these patients has become more important and more complicated. Table 5-1 below lists measurements to be monitored in shock patients and presents one author's estimation of their importance, ease, and practicability.

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[5] Ibid., p. 364.

[6] Virginia M. Graber, "Postoperative Care and Prevention of Postoperative Complications for the Multiple-Injured," Journal of the American Association of Nurse Anesthetists, Vol. 47, No. 4 (August 1979), p. 419.

[7] G. Patrick Lilia et al., "Clinical Assessment of Patients Undergoing CPR in the Emergency Department," JACEP: Journal of the American College of Emergency Physicians, Vol. 8, No. 2 (February 1979), p. 339.

[8] Robert M. Hardaway, "Monitoring of the Patient in a State of Shock," Surgery, Gynecology & Obstetrics, Vol. 148, No. 3 (March 1979), p. 339.

TABLE 5-1.

Measurement	Importance	Difficulty or expense
Arterial blood pressure	++++	
Cuff	++++	0
Catheter	++++	+
Pulse	++++	0
Hematocrit and hemoglobin	++++	0
Urinary output	++++	0
Central venous pressure, may be misleading	++++	+
Pulmonary artery pressure	++++	++
Arterial pO_2	++++	0
Arterial pCO_2	++++	0
Arterial pH	++++	0
Venous pO_2 — may be misleading	++	
Venous pH — may be misleading	++	0
Electrocardiogram	++++	0
Serum electrolytes	++++	0
Protein	++	0
Serum lactate	+++	0
Cardiac output—index—may be misleading	++	+++
Circulation time, may be misleading	++	+
Clotting mechanism	+++	0
Tissue pH	+++++	++++
Enzymes	+++	0
Blood volume — plasma volume	0	++
Blood volume — red cell mass	++	++
Peripheral resistance, may be misleading	++	+++
Accurate weight measurement	+++	+++
Rectal and toe temperature	++	+

SOURCE: Robert M. Hardway, "Monitoring of the Patient in Shock," Surgery, Gynecology and Obstetrics, Vol. 148, No.3 (March 1979), p. 341.

Most of the procedures for obtaining the measurements listed above rely upon either drawing blood or introducing a catheter. The current thrust of medical technology is to substitute noninvasive for invasive procedures. Success in this endeavor will no doubt make it easier for diagnostic criteria to be gathered by paramedics at the scene of an emergency. Coupled with computer ability to track and store diagnostic data and telemetry ability to communicate it, new tools to measure these physiological parameters in noninvasive ways should enhance the physician's skill in rescuing patients from life-threatening medical emergencies.

Some Specific Tests and Equipment

Blood gas determinations are minimally invasive, since all they need is the drawing of a blood sample. However, they are also intermittent and considerable research effort is going into making them continuous. The most promising technique employs the use of the respiratory mass spectrometer. The membrane end of a catheter is placed in the blood vessel or tissue to be sampled and the other end is connected to the vacuum outlet of a mass spectrometer. A minute amount of gas is constantly withdrawn through the diffusion membrane at a sampling rate varying from mass spectrometer to mass spectrometer within the range of 5×10^{-16} microliters per second. Only dissolved gases are drawn through the membrane, entering the catheter in quantities proportional to their partial pressures. These gases pass into the mass spectrometer, where they are quantitatively analyzed by molecular weight. The difficult part of this technique is in designing a catheter that can be implanted to sample accurately and safely for extended periods of time.[9]

Of course, the mass spectrometer method of tracking blood gas data is a more invasive technique than intermittent sampling. Attempts have been made to extrapolate blood gas tensions from expired gases and, while this approach is noninvasive, it is also less reliable.[10] The ear Oximeter is another noninvasive means of measuring blood oxygen level. It can determine blood oxygen within about ± 1 percent if the patient is in the normal range of 95-100Hg. Its accuracy falls to about 5 percent in the range of 70-75, but this is usually quite adequate.[11] In use of the Oximeter, adequate blood circulation is important; if the blood flow to the ear is impaired, the device cannot be used.

Special electrodes have been designed to respond to a specific dissolved gas and have been inserted in arteries for continuous pO_2 measurements. However, their use has been limited by

1. Contamination of the electrode surface (e.g., thrombogenesis)

2. Change in the composition of the medium which, in turn, changes the characteristics of the oxygen diffusion pathway

3. Movement of the electrode causing a stirring artifact.[12]

The employment of special CO_2 sensors has also been investigated, but they are not yet in general use.

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[9] Daniel J. Donavan, Richard P. Johnston, and Kenneth F. MacDonnell, "Respiratory Monitoring: Systems and Devices," in Kenneth F. MacDonnell and Maurice S. Segal (eds.), Current Respiratory Care (Boston: Little, Brown and Company, 1977), p. 48.

[10] Ibid., p. 47.

[11] "Blood Gas and pH Analysis," Medical Products Salesman, Vol. 9, No. 5 (May 1978), p.42.

[12] Donovan, p. 47.

The only means of obtaining an accurate measurement of central venous pressure has been by direct venous cannulation. However, a group of Swiss doctors has extended the principle of venous stop flow pressure to develop a noninvasive method of measuring central venous pressure. The method consists of venous auscultation at the thoracic inlet with a Doppler device while the patient breathes into a U-shaped manometer. The pressure at which venous flow ceases transiently is the venous stop-flow pressure. It is assumed that, in resting recumbent patients, the normal thoracic venous flow is disrupted when intrathoracic pressure rises above the central venous pressure.[13] Because patient cooperation is required, the technique is limited to conscious subjects. Nevertheless, the method is noninvasive and has no complications or contraindications.

Crushing injuries, fractures, and burn injuries give rise to an ischemia-edema cycle and subsequent muscle necrosis and tissue loss. The photoplethysmograph appears to be a promising means of monitoring the degree of vascular compromise that results from such injuries. It uses a small LED infrared emitter/detector array to measure pulsatile blood flow in an illuminated vascular bed. At the Veterans Administration Hospital in Providence, Rhode Island, it is being used to reduce the number of patients undergoing angiography because of suspected arterial blockage in the legs.[14] As a monitoring technique, photoplethysmography requires little training. It is noninvasive, portable, and relatively inexpensive.[15]

Centrifugal fast analyzers first appeared in clinical laboratories in 1968. They have now been greatly reduced in size and improved in capability, and in 1977, a portable analyzer was introduced at the Ninth Annual Symposium on Advanced Analytical Concepts for the Clinical Laboratory at Oak Ridge National Laboratory. The instrument weighs 36 pounds and occupies less than one cubic foot of space. The addition of a power pack raises total weight to about 55 pounds, or total volume is about a cubic foot.[16]

In 1975, Bell Labs developed a fluorometer that utilizes a drop of blood to determine lead content immediately. Previously screening tests for blood levels were done through atomic absorption spectroscopy. This technique required a large amount of blood and was not easily adaptable

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[13] J. A. Durr et al., "Non-Invasive Method for Measuring Central Venous Pressure," Lancet, No. 8064 (March 18, 1978), p. 586.

[14] International Medical News Service, "Poor Arterial Blood Perfusion Gauged Without Angiography," International Medicine News, Vol. 11, No. 12 (June 15, 1978), p. 51.

[15] Phillip J. Bendick, John R. Mayer, and John L. Glover, "Noninvasive Monitoring of Vascular Compromise in Tauma," JACEP: Journal of the American College of Emergency Physicians, Vol. 8, No. 8 (August 1979), p. 320.

[16] "Portable Centrifugal Analyzer Developed," Chemical & Engineering News, Vol. 55, No. 14 (April 4, 1977), pp. 5-6.

to field work. The Bell Labs fluorometer, however, is small enough to be portable and public health personnel can learn to use it with only a few minutes of instruction.[17] It can also be used to measure bilirubin levels in newborns.[18]

Abbott Laboratories is introducing a new automated microbiology system that is designed to test the effectiveness of antibiotics against specific organisms. The "MS-2" system can be used for most types of bacterial infections, e.g., pneumonia, septicemia, wound and burn infections. In the case of a burn patient, colonies of bacteria from the burn are suspended in liquid culture medium and placed in a cartridge. The cartridge is then inserted in the instrument and electro-optical scanning systems repeatedly monitor microbial growth in the presence of number of different antibiotics. Within three to six hours, up to ten antibiotics are tested for their effectiveness in suppressing growth of the organism causing the infection. The system indicates whether or not the organism is susceptible to the antibiotics and rank orders the drugs by degree of effectiveness. At $30,000 to $50,000, depending upon number of modules and optional equipment, this is a relatively expensive instrument. The advantage in using it is that it permits the use of appropriate antibiotic therapy up to eighteen hours sooner than with nonautomated testing procedures.[19]

Looking a little further into the future, we may be able to anticipate blood tests that do not require the actual drawing of blood. Nils Kaiser of the Max Planck Institute for Plasma Physics (Garching, West Germany) has developed an infrared spectroscopy technique that determines the concentrations of various substances in the blood faster and more accurately than the methods that require taking blood samples. The patient simply presses his lips against a small flat plate and, by using infrared spectroscopy principles, the equipment determines the blood's content of substances such as ethanol, glucose, cholesterin, and uric acid. It measures the blood's alcohol content to within 0.001 percent.[20]

Logistics of Emergency Laboratory Procedures

Some hospitals have found it desirable to develop specialized laboratories in juxtaposition to their emergency care units. The proximity of the laboratory saves valuable time that otherwise would be lost in

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17 "New Blood Test Can Screen for Lead Poisoning," Chemical & Engineering News, Vol. 53, No. 5 (February 3, 1975), p. 18.

18 "Bell Labs Instruments Have Biomedical Uses, "Chemical & Engineering News, Vol. 56, No. 18 (May 1, 1978), p.8.

19 "Abbott Diagnostic System Aims to Reduce Time Required to Pick Proper Medication," Chemical Marketing Reporter, Vol. 215, No. 25 (June 18, 1979), pp. 4,31.

20 "Bloodless Blood Test Under Development; Infrared Spectroscopy Is the Secret," Electronics, Vol. 51, No. 24 (November 23, 1978), pp. 74-75.

transporting specimens to the remote central laboratory. This type of arrangement is expected to become more popular in the future, because of the success of experimental trauma units. Instrumentation for emergency room or trauma laboratories should be developed with the following requirements in mind:

- Minimum of specimen handling.
- Simplicity of operation, including automatic calibration.
- Complete self-containment, except for utility connections, with sufficient reagents for a specified period of operation.
- Utility requirements limited to electricity, tap water, and waste.
- Compact design to permit maximum mobility.
- Modular components easily serviced and repaired.
- Maximum reliability of instrument operation with automatic alert for malfunction.

Test selection in the emergency situation should be limited to the half-dozen determinations generally required for immediate patient care and should include determinations for blood pH, O_2 and CO_2 content, hemoglobin, hematocrit, sodium, and potassium. Ideally, technical personnel should be able to provide the physician with reliable emergency determinations in the shortest possible time, preferably within two minutes.[21]

Implications for the Coast Guard

The trends on mineralization of equipment, improved versatility, diminishing cost of electronic equipment, improved portability, and noninvasive techniques will affect all three domains of mobile health delivery systems of interest to the Coast Guard. Automotive and airborne vehicles (ambulances) will be faster, safer and more efficient. Helicopter range and speed will be increased thus improving the rescue area open to CG SAR missions. Diagnostic and therapeutic equipment in sick bays will improve in sensitively and range of use. As for mobile laboratories to provide support for more widespread emergencies, the situation is not so clear. Each emergency situation creates its own type of patient; burn victims will need different laboratory tests and support than drowning victims. A mobile laboratory should probably be designed from a central equipment supply, so that it could be assembled to fit the needs of a particular situation. Secondly, sensitive instruments do not always travel well and may be useless or in need of adjustment upon arriving at the proposed site

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21 Thomas D. Kinney, and Robert S. Melville (eds.), Mechanization, Automation, and Increased Effectiveness of the Clinical Laboratory, 1976 Edition, DHEW Publication No. (NIH) 77-145 (Washington, DC: U.S. Department of Health, Education, and Welfare, 1977), p. 61-62.

of their use. Thirdly, and most important, is the fact that sophisticated diagnosis is not needed unless treatment is to be initiated. If treatment is to begin, physicians as well as equipment will have to be on the scene and facilities for treatment must be available. New missions for the Coast Guard may well require the development of this kind of support capability.

6. NEW COAST GUARD MISSIONS RESULTING FROM MEDICAL DEVELOPMENTS

Introduction

Prospective biomedical developments can not only affect existing programs within Coast Guard Missions, they can lead to both completely new programs and new missions. This chapter is concerned with identifying and describing these new programs and missions. To conduct this search, developments in biomedical technology were reviewed within the taxonomy described in Chapter 2; each technology was classified as diagnostic, preventive, therapeutic or rehabilitative, organizational, or supportive. In each of these five categories, a distinction was made among technologies, depending on whether they focus on techniques, drugs, equipment, or procedure. (See Figure 6-1.) The Coast Guard missions (Table 6-1) were reviewed in light of the prospective developments and new missions and programs were identified. Of course, not all of the cells of the matrix shown in Figure 6-1 contained developments that triggered new program or mission concepts.

For each development considered, the number of the cell in Figure 6-1 is first stated, followed by a brief statement of the development. This is followed by a discussion of its possible influence on the development of new Coast Guard missions and programs. Relevant assumptions are also indicated. Where appropriate, mention is made of other agencies that might be involved.

TABLE 6-1. COAST GUARD MISSION TAXONOMY.

OPERATIONAL PROGRAMS	SUPPORT PROGRAMS
Short Range Aids to Navigation	Public and International Affairs
Bridge Administration	Communication Services
Commercial Vessel Safety	Engineering
Enforcement of Laws and Treaties	Financial Management, Personnel and Supply
Ice Operations	Civil Rights
Marine Environmental Protection	Medical
Military Operations	Legal
Military Preparedness	Intelligence and Security
Marine Science Activities	Personnel
Port Safety and Security	Hazard Control, Safety
Radionavigational Aids	Research and Development
Boating Safety	Retired Pay
Reserve Forces	
Search and Rescue	

	TECHNIQUES	DRUGS	EQUIPMENT	PROCEDURES
DIAGNOSTIC TECHNOLOGIES	1	2	X 3	4
PREVENTIVE TECHNOLOGIES	X 5	6	7	X 8
THERAPEUTIC OR REHABILITATIVE TECHNOLOGIES	9	10	11	12
ORGANIZATIONAL TECHNOLOGIES	X 13	14	15	X 16
SUPPORTIVE TECHNOLOGIES	X 17	X 18	19	X 20

FIGURE 6-1. BIOMEDICAL TAXONOMY.

Diagnostic Technologies/Equipment (Cell 3)

Design of an automated system to test the effectiveness of various antibiotic agents against microorganisms.

- Assumption: There is an increase in the incidence of dangerous outbreaks due to virulent, possibly new or changed microorganisms that may have peculiar, possibly critical sensitivities or resistances to particular antibiotics (e.g., infection with a microorganism such as a variant of Legionnaire's Disease bacterium may rapidly give rise to a deadly pneumonia unless there is very early treatment with erythromycin rather than penicillin, although the latter is more commonly used today to treat pneumonia due to an unidentified bacterium). The increase in incidence may be due to

  ° biological warfare, overt or covert.

  ° the aftermath of biological warfare.

  ° an accident arising from research associated with preparation for biological warfare.

  ° "spontaneous" adaptation of existing microorganisms to antibiotics now in use.

  ° an accident arising from genetic engineering or plasmid technology.

  ° "spontaneous" emergence of new or altered microorganism species, e.g., by introduction of new genetic information carried by viruses or virions entering the atmosphere from space.

If the prevalence of virulent diseases increases, and if identification of microorganism sensitivity to particular antibiotics becomes critical, for example, for prevention of the spread of dangerous epidemics, then the Coast Guard may acquire the mission of screening individuals entering or approaching the coasts of the United States to determine whether they carry possibly dangerous microorganisms and to determine therapeutic, if any, countermeasures that may be effective against any such microorganisms the individual may carry. This would be a new operational mission, part of a new operational program, not now in the mission taxonomy. Doubtless, however, the screening operation would be conducted under an umbrella of new laws and treaties plus extensions or new applications of existing ones. Therefore, strictly speaking, the new mission might be considered to fall under the present operational program, Enforcement of Laws and Treaties. However, the special gravity and unique requirements of the new mission would probably lead to its being placed in its own, new operational program. There would be precedent for this: In a sense, all Coast Guard programs are implementations or enforcements of laws and treaties, but nevertheless many programs are classified as distinct from Enforcement of Laws and Treaties, because the emphasis is special and does not focus, for example, on prevention or detection of violations.

A similar new mission that the Coast Guard might acquire would be to screen animals, plants, and inanimate objects such as foodstuffs. Because some diseases may be carried by air or water, the Coast Guard may also acquire the mission of screening or monitoring the waters and air near and about the nation's borders.

Other agencies that might be assigned one or more of these missions, either in addition to, in conjunction with, or instead of the Coast Guard, include Customs, Immigration and Naturalization Service, the Public Health Service, the Department of Agriculture (in connection with microorganisms that affect agriculture), the Fish and Wildlife Service, the Department of the Interior, the Environmental Protection Agency, and some new division of the National Institutes of Health such as a National Institute on Genetic and Plasmid Technology.

Preventive Technologies/Procedures (Cell 5)

Manipulation of the physical and social environment.* Actuarial analyses of the incidence of accidents and diseases in relation to the work environment and nonwork environment of Coast Guard personnel will be facilitated by the recent and continuing advances in computer technology. In addition, there has been of late development of increasing sophistication in the mathematical and statistical theoretical underpinnings of these analyses.

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*R. H. Egdahl and D. C. Walsh (Eds.), Health Services and Health Hazards: The Employees Need To Know, Springer, 1978; W. J. Filstead, J. J. Rossi, and M. Keller (Eds.), Alcohol and Alcohol Problems: New Thinking and Directions, Cambridge, Mass.: Ballinger, 1976; J. R. Tappan, Prevention of Alcoholism and Other Drinking Problems in the U.S. Navy, Naval War College Advanced Research Project No. 077, Washington, D.C.: Department of the Navy, 1973; Timo Klaukka, "Positive Elements of Health in the Measurement of Disability," unpublished, Helsinki, Finland: Social Insurance Institution, Research Institute for Social Security, filed in 1978.

These analyses should make possible much better understanding of the nature of and types of hazards in the work and nonwork environments of Coast Guard personnel. It may be expected that presently overlooked or underestimated factors will prove to be significant in the causation of life-threatening or health-threatening occurrences.

It is likely, therefore, that practical manipulations of the physical and social environment will become a standard way to seek to reduce such hazards. Coast Guard management will take these matters into account in making decisions concerning:

- Location of facilities

- Numbers of personnel assigned to a given location or ship

- Equipment safety

- Levels of air pollution

- Availability of sources of health hazard (e.g., tobacco, junk food, alcohol, drugs)

- Availability of resources favorable to good health (e.g., exercise facilities, facilities providing mental stimulation).

This sort of management will require a high level of professional expertise plus the handling of large amounts of complex data. Therefore, both in society at large and within the Coast Guard, we will probably see the emergence of new subprofessions or job classifications, e.g., physical and social environmental hazard specialist. There will have to be several levels of professional responsibility. At the lowest level, there may be a hazard analyst, perhaps with an Associates degree, who will be qualified to apply standard evaluation techniques to rating the hazardousness of particular work or nonwork environments. At the highest level, there may be a new profession requiring years of postdoctoral training. Probably many of those working at the highest level will be physicians. At this level, the specialist will be qualified to supervise the complex social and organizational arrangements necessary to gain acceptance of and minimize the cost of major physical and social environmental manipulations.

Manipulation of the physical and social environment has long been done by the Coast Guard and other organizations, but incidentally and unsystematically. What is anticipated here is that such efforts will be brought together into a systematic operation directed by its own specialists and funded explicitly--a new Coast Guard mission. This new mission will fall under the Coast Guard support programs. Probably, no new support program will be defined. Rather, the new mission will be considered an extension of existing <u>Hazard Control, Safety</u> programs. The focus in the new mission will be not merely on eliminating immediate safety hazards but also on creating an environment that in the long run promotes health and well-being. Not only will attention be given to, for example, ensuring that electrical equipment is properly grounded; in addition, attention will be given to the long-term health impacts of living and working in an environment in which there is long-term exposure to low-frequency (e.g., 60-cycle) electromagnetic energy. The present Hazard Control, Safety program has focused on the immediate rather than the long-term hazards, and this may well change.

Preventive Technologies/Techniques (Cell 8)

Understanding and control of psychological factors in health maintenance.* Recent evidence has pointed increasingly to the fundamental unity of mind and body and to the key role of matters of attitude or morale in both health and disease. At present, however, there is only nebulous understanding of the detailed connections between psychological processes and the acquisition and maintenance of good health or the acquisition and maintenance of particular disease states:

- Assumption: The steadily increasing understanding of the roles of the physical and social environment in health and disease will lead to a growing body of detailed understanding of the role of psychological factors. Development of this increased understanding will be greatly facilitated by heavy support of research in this area, particularly support by the National Institutes of Health.

In addition, as disease less and less often becomes a source of mortality or morbidity in the age range in which persons are on active duty with the Coast Guard, there will be increasing attention to sources of mortality and morbidity not falling within traditional definitions of disease, e.g., suicide, homicide, alcoholism, depression, or accidents. Here, it is generally agreed that psychological factors are of great importance.

As in manipulation of the physical and social environment, discussed above, the Coast Guard, like most other organizations, has long sought to foster psychological states that favor good health. The new, growing body of expertise will make possible more effective efforts. These more effective efforts could be brought together organizationally under a single, coordinated mission umbrella.

It is likely that there will not be a new mission aimed solely at control of psychological factors affecting health. Rather, this sort of effort is likely to be seen as part of the mission of the specialists who address the influences of the physical and social environments. Probably within the new set of professional and subprofessional specialties and subspecialties concerned with environmental influences on health and

*A. Rohe, "Life Change and Illness Studies--Past Histroy and Future Directions," Journal of Human Stress, March 1978, pp. 3-15; "Life Situation, Emotion and Disease," Psychosomatics, Vol. 19, December 1978, pp. 747-753; Tessler, Mechanic, and Diamond, "Effect of Psychological Stress of Physician Utilization--A Prospective Study," Journal of Health & Social Behavior, Vol. 17, 1976, pp. 353-364; T. Miller, J. G. Ingraham, and S. Davidson, "Life Events, Symptoms and Social Support," Journal of Psychosomatic Research, Vol. 20, 1977.

disease, there will be subspecialties focusing on psychological factors. Organizationally within the Coast Guard, therefore, it is likely that the forthcoming development of better understanding and control of psychological factors influencing health and disease will modify the definition and operation of the forthcoming new support mission concerned with manipulation of the physical and social environment, rather than generate a separate new mission.

Health education employs behavior modification techniques.* A particular psychological technology that is likely to be of increasing importance is behavior modification, using contingency management. This approach, stemming originally from work by B. F. Skinner and his students, involves modifying behavior by first determining what is rewarding or reinforcing to the individual, then making provision of the reward or reinforcement contingent upon the individual's exhibiting desired behavior. The technique is usually well accepted by trainees because it operates by providing reward rather than by using punishment or some other unpleasant manipulation. It is well suited to application under conditions of controlled or limited environment such as on a small vessel. It has also been widely applied in the design of self-instructional books or programs in which the reinforcement is simply being informed by the training device or book that one has provided the correct response to a question or challenge posed by the program. An advantage of this approach is that it is possible to use it in self-paced work in which each individual proceeds at his or her own rate; different trainees can skip the parts of a training program with which they are already familiar. The system is also readily adapted to provide ongoing appraisal or performance scores for those who are being trained, thus making possible simple and efficient definition of credentials such as certificates of completion of a given course of study. Behavior modification has also been used successfully as a psychotherapeutic technique. Here, specially tailored training programs can be used to seek to modify unique behaviors in particular individuals. For example, a person who has a particular phobia may be trained to accept and be comfortable with the formerly phobic object or situation.

Within the Coast Guard, aside from its occasional use in psychiatry, behavior modification is likely to be used primarily as an educational or training method. Health education training will be particularly likely to involve this new technology. The curricular goals of behavior modification programs in health education are likely to be set by staff involved in the mission discussed immediately above: manipulation of the physical and social environment and control of psychological factors relevant to health and disease. A typical program might seek to teach understanding of the health hazards of smoking. Another might help smokers give up the habit.

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*C. I. Cohen and E. J. Cohen, "Health Education Panacea, Pernicious or Pointless," (Editorial) New England Journal of Medicine, Vol. 299, September 28, 1978, pp. 718-720; A. Dean, A. Kraft, and B. Popper, "Primary Groups," Chap. 7 in The Social Setting of Mental Health, New York: Basic Books, 1976; Preventive Medicine USA, "Health Promotion and Consumer Education," Prodist, New York, 1976.

Actual development and preparation of such training programs is a highly specialized technology. Most likely, the Coast Guard would purchase such programs rather than prepare them in-house. Nearly all of the health education objectives of the Coast Guard would correspond to those of other large organizations, and so it is likely that there will be available a wealth of materials on the market suitable for purchase.

Here again, what is envisioned is not emergence of a new mission tied to this new technology. Rather the support program mission addressing social, physical, and psychological factors influencing health will be affected by this technology.

Matching medical evaluation characteristics of personnel to their assignments or billets.*

- Assumption: A new subdiscipline that will emerge will be clinical or medical personnel management. Traditional personnel management seeks to assign persons to jobs so that the capability requirements of the jobs correspond with the capabilities of the persons assigned to them. However, special limitations due to medical conditions or handicaps might relate to particular job demands. Similarly, traditional personnel management does not look systematically at the health impacts of jobs (this will be the function, in part, of the new concern with physical and social environmental factors), nor is there analysis of how job demands on capabilities might be modified to accommodate handicaps or medical limitations (such as those due to advanced age). The development of clinically or medically oriented personnel management will be favored by

    ° the aging of the population

    ° improved capacity to detect and make detailed evaluations of handicaps

    ° improved capacity to keep alive functioning persons who previously would have died

    ° availability of a wide variety of prosthetic devices that will permit some approximation of normal functioning for even severely handicapped persons (e.g., blind-deaf persons with prosthetic sensing devices)

    ° new regulations, court decisions, and legislation requiring accommodation to the needs of the handicapped.

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* C. U. Granger, G. Albrecht, and B. Hamilton, "Outcome of Comprehensive Medical Rehabilitation: Measurement by PULSES Profile and the Borthel Index," Archives of Physical Medicine and Rehabilitation, Vol. 60, April 1979, pp. 145-153.

Particularly at induction, the medical evaluation will focus on detection of medical conditions and handicaps that may be relevant to job assignment or billeting. Again, it is not anticipated that there will be a new Coast Guard mission tied specifically to this development. Rather, the new mission discussed above--consideration of physical, social, and psychological factors in health--will be strongly influenced by the emergence of clinical personnel management. If, however, a new distinct mission does emerge, then it will probably be administered under the Personnel support program. Coast Guard personnel will be matched to their assignments, to the advantage of both the personnel and the Coast Guard. For example, work requiring high levels of vigilance will be analyzed to determine the exact demands--e.g., whether the vigilance must be for a visual or for an auditory signal, or whether the vigilance required is general alertness. Timing of the vigilance demands will also be studied: intermittent or continuous, prolonged or of short duration, predictable or unpredictable. With such information, particular handicaps might be accommodated or might even prove advantageous. For example, a blind person might do better than a sighted person in prolonged vigilant listening for an unlikely, faint sound.

Organizational Technologies/Procedures (Cell 16)

Remote health care via telecommunications.* As discussed elsewhere in this report, telecommunications centers for relay of health care information may be anticipated. Telecommunications will also be used for viewing and directing health care from a distance, with physician extenders often providing care at the site.

- Assumptions: The present rapid growth and development of communications technology will continue. This will be favored by continued high costs of energy, because communications are fundamentally cheaper than transportation, because less mass must be moved when sending images than when sending objects. Costs of communication will continue to drop, and available channels and bandwidths will continue to increase.

There should be two noteworthy mission impacts: one on the operational program, Search and Rescue; the other, on the Medical support program.

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*R. I. Bashshur, P. A. Armstrong, and Z. I. Youssef (Eds.), Telemedicine: Exploration in the Use of Telecommunications in Health Care, Springfield, Illinois: Thomas, 1972; W. T. Rasmussen and J. Silva, Navy Remote Medical Diagnosis System, San Diego, California: Naval Electronics Laboratory Center, 1976; G. T. Moore et al., "Comparison of Television and Telephone for Remote Medical Consultation," New England Journal of Medicine, Vol. 292, No. 14, pp. 729-732; LTC Barry W. Wolcott and 1Lt Robert E. Stieneker, "The Use of In-Barracks Screeners To Improve Military Sick Call," Military Medicine, Vol. 144, No. 2, February 1979; Telehealth Handbook, A guide to telecommunications technology for rural health care, U.S. DHEW Publication PHS 79-3210, May 1978; U.S. DHEW, Public Health Service HRA, NCHSR, Computer Based Patient Monitoring Systems, DHEW Pub. No. (HRA) 76-3143, 1976.

Search and rescue missions can bring Coast Guard personnel face to face with extreme medical emergencies. Requisite medical equipment, e.g., for differential diagnosis or for evaluation of the severity or urgency of existing medical problems, may be thousands of miles away. Properly qualified personnel, e.g., specialist physicians or surgeons, may also be far away. Today, therefore, a major focus in search and rescue is on an essential ambulance service: prompt and safe conveyance of the injured or sick person to a site where appropriate equipment, personnel, and care facilities may be provided. There are, of course, often life-threatening delays when the distances that must be traversed or the hazardous travel conditions involved on occasion appreciable transport delays.

A new mission dimension that the Coast Guard may acquire, therefore, may be on-site provision of medical services in a remote site, supported by telecommunications. At the home-base end of the telecommunications line might be

- a physician specialist team to direct the remote medical services.
- diagnostic analytic devices capable of processing information about a patient transmitted via the telecommunications system.
- medical reference and support services such as medical library services.

At the remote site might be

- physician-extender personnel.
- remote controlled devices whereby personnel at the home-base end of the telecommunications line might act directly upon a patient or the patient's surroundings (for example, to control positioning or a speculum used in remote examination of the patient).
- sensing devices used for gathering physiological data and also to substitute for the sorts of information physicians gather through direct appraisal of physical signs (e.g., to permit remote monitoring of chest and abdominal sounds).

It is not anticipated that routine medical services will be provided in this way, but as an emergency service, this may be the only way to save lives or prevent severe permanent disabilities.

It is anticipated that the new mission of provision of emergency medical services via telecommunications will be subsumed under the present operational program, Search and Rescue. From time to time, also, a medical emergency involving Coast Guard personnel or others not requiring search and rescue services may nevertheless call for emergency medical services via telecommunications. Such services might properly be subsumed under the present Medical support program; however, because much the same equipment, personnel, and home-base facilities would be used for corresponding search-and-rescue operations, it is likely that these medical services will be administered under search and rescue.

The equipment that would be needed at the remote site would not be inexpensive. Therefore, as soon as possible remote emergency medical services would be replaced by ordinary on-site services, so as to free the equipment for use elsewhere. Therefore, a related activity associated with this mission would be swift transport of key remote sensing and manipulating devices to sites where they were needed.

Organizational Technologies/Techniques (Cell 13)

Medical and insurance services to retired persons--part of standard package--contingent on suitable lifestyle.

- Assumption: As understanding of the relationship between lifestyle and health grows, providers of medical insurance will take an increasing interest in the lifestyles of those they insure. Related cost considerations will encourage all organizations that provide medical services to take active roles in promoting lifestyles that favor health for those to whom they provide the medical services. In the case of government workers or retirees, legislation or regulation may seek to enforce this.

The Coast Guard services to retired personnel may be adjusted to reflect the extent to which particular medical problems may be attributed to negligence on the part of the person suffering from the problem. For example, benefits for lung cancer may be reduced if the individual has a history of persistent heavy smoking, despite repeated warnings from qualified medical advisors that the smoking appeared to be damaging the person's lungs and creating conditions favorable to the development of lung cancer. Alternatively, certain lifestyles that have adverse medical implications might impose upon the individual a special tax or premium to pay for the increased expected costs of health services. Thus, instead of reducing benefits for lung cancer if the individual was a heavy smoker, the individual might be required to pay an extra premium while still healthy in order to continue to be eligible for insurance.

The new Coast Guard mission foreseen here is related to but distinct from the new mission discussed above: addressing the physical, social and psychological influences upon the health of Coast Guard personnel. Clearly, one aspect of lifestyle is choice of a particular physical or social environment, which may have important health implications. This aspect would fall directly under the other new mission discussed above. In addition, there are clearly psychological aspects of deliberate choice, for example, to smoke although it is clear that the smoking is very dangerous to the individual's health. (For example, in thromboangina obliterans, smoking will almost certainly lead to fatal capillary disorders, but some people literally smoke themselves to death rather than give up smoking when they develop this rare disease.) Moreover, teaching people about the health implications of particular lifestyles, or training them to adopt a more healthful lifestyle, may well be done using contingency managment behavior modification techniques.

What is unique here is the necessity to perform regular health and lifestyle appraisals on retired personnel. Even with regard to present Coast Guard personnel, what is envisioned here may involve a degree of invasion of privacy not presently customary. What may evolve may be a procedure whereby an individual may, in effect, buy privacy by accepting the same increased costs as would be occasioned by discovery that the individual's lifestyle was unhealthy. This would be like giving a person the right to refuse to take a test to determine whether he or she was intoxicated, but making the consequences of refusing to take the test the same as being found to be intoxicated (which is the law presently with respect to the penalties for driving while intoxicated).

Because it is likely that similar contingencies relating medical services to lifestyle will apply to a wide range of retired persons, probably to all retired federal employees, it is quite possible that the mission of performing regular health and lifestyle appraisals on retired Coast Guard personnel may not be assigned to the Coast Guard, but instead a single federal agency may be made responsible for all such appraisals of persons in federal retirement systems. This agency may be the present Social Security Administration, if it continues to be responsible for programs such as Medicare. If, as seems likely, the Medicare program will be detached from the Social Security Administration as part of a general revision of federal involvement in health insurance, then most likely the appraisal mission will become the responsibility of any new federal health insurance agency. If the armed forces set up a retirement health care system more extensive than that available to other federal retirees, then a single agency tied to the armed forces, such as Civilian Health and Medical Program for the Uniformed Services, may be made responsible for appraisals of persons in armed forces retirement systems.

If the Coast Guard does acquire the appraisal mission here envisioned, it will, of course, be considered a support mission and is likely to fall within the present Retired Pay support program.

Supportive Technologies/Techniques (Cell 17)

Regimens for life-expectancy prolongation and aging retardation.*

- Assumption: Growing understanding of the biological bases of aging will lead to practical procedures for prolonging life expectancy and retarding aging. Cost considerations

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* Theodore J. Gordon, Herbert Gerjuoy, and Mark Anderson, A Study of Life-Extending Technologies: Study Findings, Glastonbury, Connecticut: The Futures Group, March 1977.

will lead to the focus of research and development being on regimens, rather than on high-technology, life-support techniques. These developments will be related to the expected growth in understanding of the influences upon health of the physical and social environment, and of lifestyle.

As it becomes more generally known that particular daily schedules, diets, levels of stress, etc., may either slow or speed aging, prolong or shorten life expectancy, the public in general and Coast Guard personnel in particular may increasingly shun those circumstances and situations which favor aging and death. The Coast Guard will therefore need to offer either special inducements such as hazard pay for jobs or assignments not conducive to aging retardation or life extension, or alternatively adjust daily schedules, diet, stress, etc., so that personnel may live under favorable regimens.

Therefore, a new support mission, under the Medical support program, will be analysis and appraisal of present Coast Guard procedures and management of reorganizations, where necessary, so as to make them conducive to daily regimens that favor health and long life.

This mission will also, like so many others discussed here, be closely related to the new mission foreseen: manipulation of the physical and social environment to foster good health. Very probably, the same senior personnel who will supervise such manipulations will also be involved in management of any reorganizations necessary to make work in the Coast Guard conducive to health and long life. Therefore, the new mission here proposed will probably have the same organizational home as will the manipulation mission discussed earlier. If the manipulation mission does not get assigned to the Medical program, then probably neither will the present mission, which focuses on regimens.

Supportive Technologies/Drugs (Cell 18)

Drugs that control motivation and emotion. Drugs that affect motivation and emotion have long been known. The opiates tend to reduce all sorts of strong arousal, particularly fear. Alcohol has similar effects, particularly in large doses. Caffeine is a mild psychic energizer. Recently, rapid progress in understanding of the chemical bases of the various motivations and emotions has made it seem more and more likely that there will soon be available a wide variety of drugs that will turn on, turn off, block, or maintain virtually any motivation or emotion. Quite possibly, the entire gamut of human effect, from sexuality to anxiety, from calm attentiveness to berserk rage, will be subject to precise, detailed control.

This new technology will undoubtedly create profound social problems. Deep issues of morality and politics are touched upon by any widespread use of this technology. It seems likely that early widespread applications in a free society will be within organizations, such as the armed forces, in which needs for personnel efficiency and responsiveness to organizational demands are generally felt to override the general desire for free personal self-control by every individual citizen. It is, therefore, possible that the Coast Guard will be among the first organizations to make wide use of the new technology. Indeed, it is possible that only agencies such as the Coast Guard will ever be permitted to make wide use of it.

The Coast Guard could, for example, use the new drug technology to suppress unwanted sexuality, anger, or fear. It could use it to help personnel give full attention to difficult, critical tasks under hazardous, distracting circumstances such as prolonged work without rest in a life threatening situation (such as a natural disaster such as a hurricane, or even in the event of exposure to hostile military action). It is now generally an axiom of military doctrine that in the battlefield setting many persons engage in a variety of random, counterproductive activities, largely due to the intense excitement and fear produced by the modern combat situation. It is likely that the same sort of disruption occurs in other severe crises situations. Calming drugs could be of great value.

Another important area of application would be in control of undesired interpersonal responses that might otherwise arise when personnel are confined together in close quarters for long periods--as in, for example, missions in small vessels or in billets at very remote locations. At times, both rage and sexuality have been unwanted emotions difficult to contain or control in such settings. The new drug technology may greatly ease the problem of maintaining personnel efficiency on such missions.

Once more we envision here a new support mission. It will probably be administered under the Medical support program, and very likely it will be related to the new mission envisioned in connection with manipulation of the social environment, because control of various interpersonal feelings by drugs will be an alternative to other, often much more costly, ways of maintaining a desirable social ambience.

Because of the great moral and political sensitivity of such a use of drug technology, it is likely that there will be some sort of governmental watchdog agency to oversee its use, even within the government. Therefore, there may be involvement of the Department of Justice in the mission, or of some new agency, which might act as a sort of ombudsman to permit personnel to protest or appeal what they might consider to be unwarranted tampering with their emotions or motivations.

Supportive Technologies/Procedures (Cell 20)

Space technology and automation make feasible prostheses by-passing neural and muscular disabilities.* Above, in connection with discussion of matching medical evaluation characteristics of personnel to their assignments or billets, it is assumed that a wide variety of prosthetic devices

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*R. A. Dudek et al., Technology Assessment: Human Rehabilitation Techniques, Lubbock, Texas: Texas Tech University, 1976.

will become available that will permit approximation of normal functioning for even severely handicapped persons. For example, it will become possible for totally paralyzed individuals to move automated extensions of themselves. This can be done using detectors that pick up nerve impulses moving down motor nerves to paralyzed muscles, or even pick up signals in the brain itself. (Technology of this kind was originally researched in connection with development of devices to permit persons to control equipment, despite extreme acceleration, as in critical space maneuvers.) Consequently, this new technology will have direct implications for the feasibility of and the management of taking into account the medical evaluation characteristics of personnel when determining assignments to tasks or to billets.

The same combination of space technology and automation will make feasible remote control of automated extensions of personnel for operation in hazardous environments such as high radiation, deep sea, or high temperature. This will have direct bearing on the new mission discussed above: remote emergency medical services via telecommunications. The same technology that will make it possible for a remote extension of a person to move about on the bottom of the sea, seeing through the television eyes and listening through the microphone ears of the remote device, moving its arms and manipulators, etc., will also make possible performance of medical and medical-support tasks (such as nursing services) by means of remote surrogates.

In addition, however, the new technology will make possible a variety of quite a few new missions for the Coast Guard. Access to hazardous or extreme environments could be very important in a number of applications. One could be searching the sea bottom for hazardous objects, including underwater mines (which might include nuclear devices). Another important mission might be exploration of the ocean floor for possible valuable natural resources such as mineral deposits. Emplacement of radionavigation aids in difficult locations could be facilitated by use of remote surrogates. The latter application would undoubtedly fall under the present operational program, Radionavigational Aids, but search of the seas for hostile devices or for mineral resources would be a pair of new Coast Guard operational missions that would probably fall under new operational programs of their own. Search for hostile devices would be, of course, related to the present Military Operations, Military Preparedness, and Port Safety and Security programs, but the new mission seems sufficiently specialized and unlike those now in the present programs to call for a program of its own.

Resource exploration might well be subsumed under the present Marine Science Activities operational program, but probably again the specialized nature of the search procedure would favor creation of a separate program. However, under Marine Science Activities there might well be one or more new missions involving use of remote sensing and manipulation capabilities for purposes broader and more scientifically fundamental than resource exploration. This might include study of underwater currents (e.g., by drifting remote sensors), emplacement of monitoring devices, exploration of the ocean deeps, and investigation of underwater seismic and volcanic activity.

Because of the critical nature of any monitoring of the ocean bottom for possible hostile devices, the assignment might well go not to the Coast Guard but rather to some other branch or branches of the armed forces. However, because of the Guard's traditional role in defending the nation's sea frontier, it is quite possible that the Coast Guard will be given primary if not total responsibility.

Exploration in the search for resources might be assigned to a variety of other governmental agencies. They might include the Department of the Interior, the Department of Energy, or a new energy resources development authority. In addition, the ocean floor within the territorial waters of the United States might be explored by private organizations operating under contract to a supervising federal agency, or operating in connection with leasing of mineral exploration rights.

A more or less military mission using remote sensing and control technology that might also be assigned to the Coast Guard would be patrol of the Arctic frontier, or of the Antarctic, particularly under adverse weather conditions or during the polar winter night. Such a mission would probably be subsumed under the present Ice Operations operational program, but it might be given a program of its own or be administered as a Military Operations mission.

Another sort of adverse environment is one in which the adversity is provided not by nature but by humans. Operations on board potentially hostile vessels--either suspected criminal or suspected hostile foreign--might be more safely and appropriately conducted by means of remote surrogates rather than by actual boarding by human personnel.

Conclusions

Clearly, new therapeutic or rehabilitative technologies seem least likely to affect or give rise to new Coast Guard missions, while it is in connection with Techniques, i.e., technologies that involve no specialized equipment, that there is likely to be the greatest impact. Preventive techniques involving regimen and lifestyle control, or control of the environment, will be of particular importance, and the Coast Guard will quite likely become involved in a variety of supportive missions in connection with application and implementation of these new technologies.

Table 6-2 displays a summary of new Coast Guard programs and missions. New programs are indicated in italics. In addition, the right-hand column gives the titles of new missions discussed in this chapter.

TABLE 6-2. NEW PROGRAMS AND MISSIONS.

ORIGIN OF SUGGESTION	OPERATION AND SUPPORT PROGRAMS	NEW MISSIONS
Cell 16	Search and Rescue	Telecommunications support of SAR
Cell 3	*Microorganism Screening*	• Screening of individuals, plants, and animals of suspect microorganisms • microorganism countermeasures
Cell 16 Cell 17	Medical Support	• Emergency medical telecommunications support • Life-extension regimens • Psychotropic drug regimens
Cell 8	Personnel Support	• Matching personnel to billets
Cell 5	Hazard Control, Safety Support	Creation of an environment that promotes well-being
Cell 13	Retired Pay Support	Health and lifestyle appraisal

7. FUTURE DEMAND FOR MEDICAL SERVICES IN THE COAST GUARD

The number of merchant vessels in service throughout the world has been increasing greatly over the past decades. As Figure 7-1 shows, the number of vessels larger than 100 tons has increased from about 34,000 in 1960 to about 69,000 currently. U.S. merchant vessels comprise only a small portion of the total: 4,700 in 1978. The U.S. figure is low because significant advantages are realized by ship operators who register their vessels under non-U.S. flags. The advantages of foreign registry include lower taxes, lower crew costs and less-stringent safety regulations and inspection requirements.

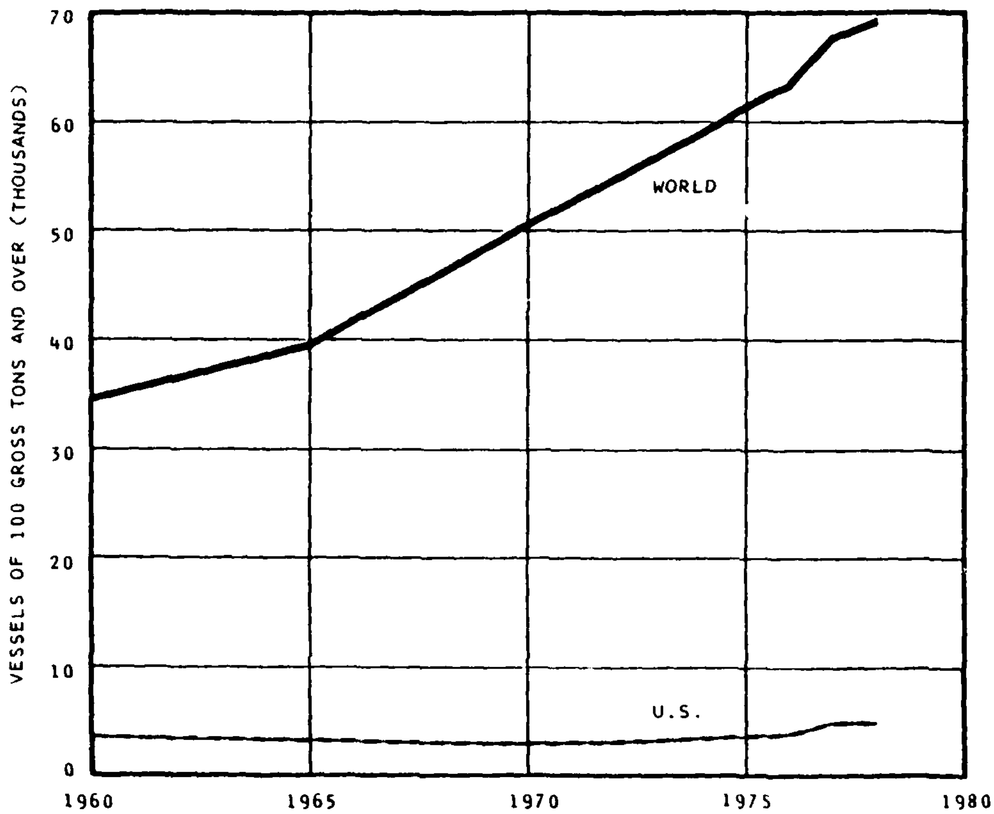
It seems likely that world trade will expand in the next few decades and, with this expansion, the number of merchant ships will increase. Since search-and-rescue missions are highly correlated with the number of merchant ships (this is established later in this chapter), it is important to forecast the number of ships in estimating future medical demands on the Coast Guard. Figure 7-2 presents our projection of the size of the world merchant fleet. This projection, as is the case for all forecasts which appear in this chapter, is accomplished using the Trend Impact Analysis (TIA) program. This procedure is explained in detail in Appendix B. TIA is based on inclusion of future events which, if they occurred, could reflect historical trends. In the case of merchant ships, the forces for change which we considered include

- the diminishing of average ship size. This event might occur as economies of scale are sought, particularly for large petroleum tankers and carriers of other bulk commodities.

- world trade expanding at a faster-than-historical rate. Although there are hints at the rebirth of protectionism, the world community has generally expressed a desire, and manifested that desire in the General Agreement on Trade and Tarriffs (GATT), to increase world trade. Most economists agree that interdependency is the likely development in the 1980s and 1990s.

- stricter marine regulations. In an effort to improve marine safety, a number of international conferences have been held by the Intergovernmental Maritime Consultative Organization (IMCO) to establish worldwide standards for safety regulations and ship inspection.

- oil spills and other environmental concerns leading to small ships. Very large crude carrier (VLCC) accidents and oil spills have raised the real possibility of the need to limit absolute ship size in order to minimize environmental threats. Although this future event is contrary to the first one listed above, either of them seems possible in the years ahead.



SOURCE: U.S. BUREAU OF THE CENSUS, STATISTICAL ABSTRACT OF THE UNITED STATES, 1979 (WASHINGTON DC, 1979).

FIGURE 7-1. NUMBER OF MERCHANT VESSELS OVER 100 TONS.

These events were assigned probabilities and their impacts were estimated. The TIA procedure was used to combine these estimates of probabilities and impacts with an extrapolation of the recent history of growth of the number of merchant ships. The resulting forecast is presented in Figure 7-2. As this figure indicates, consideration of the historical trend and the future events listed above leads to a projection of approximately 117,000 ships and over 100 tons by the year 2005; the range of uncertainty is rather high and extends from 102,000 to 129,000 over the interquartile range.

The dominance of the merchant fleet in SAR requests is shown in Figure 7-3. Figure 7-4 shows the very excellent correlation between the historical size of the world fleet and SAR responses (broken lines). The data this figure is based on extend from 1960 through 1979. (Data points are identified for 5-year intervals, as well as the projection for 2005.) To assume this relationship remains constant may be too pessimisitic since,

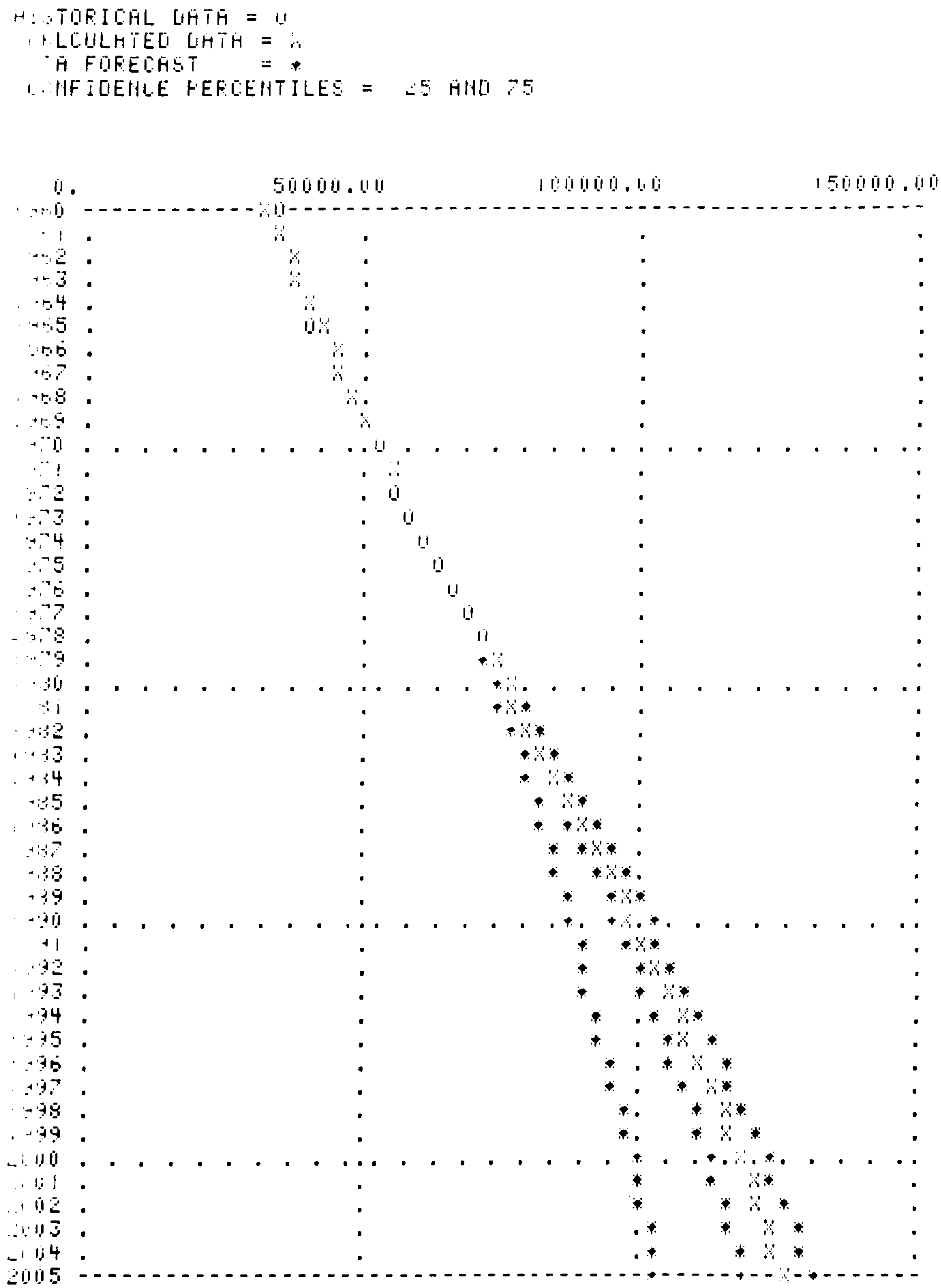


FIGURE 7-2. FORECAST OF MERCHANT VESSELS OVER 100 TONS.

TREND IMPACT ANALYSIS

YEAR	HISTORY/ BASELINE	*** LOWER	FORECAST CENTER	*** UPPER
1960	34100.00			
1965	39600.00			
1970	50500.00			
1972	55300.00			
1973	57300.00			
1974	59000.00			
1975	61500.00			
1976	63600.00			
1977	67900.00			
1978	69000.00			
1979	71420.67	70412.21	71361.15	72072.88
1980	73799.08	71841.67	73614.58	74634.50
1981	76179.91	73479.93	75862.50	77144.31
1982	78558.37	75097.87	78056.47	79653.86
1983	80929.67	76590.97	80187.82	82263.25
1984	83289.11	77899.02	82247.99	84999.47
1985	85632.05	79226.17	84276.21	87620.56
1986	87954.00	80548.09	86268.22	90161.61
1987	90250.64	81850.09	88220.00	92635.78
1988	92517.82	83122.21	90127.78	95048.30
1989	94751.64	84357.12	91988.05	97400.50
1990	96948.43	85549.24	93797.61	99693.54
1991	99104.79	86721.59	95570.05	101937.99
1992	101217.60	87892.34	97303.85	104126.81
1993	103284.05	89009.40	98980.55	106254.09
1994	105301.62	90152.77	100668.35	108382.34
1995	107268.10	91347.70	102369.53	110502.41
1996	109181.61	92619.05	104086.47	112605.66
1997	111040.55	93837.08	105747.62	114650.50
1998	112843.64	95001.17	107351.92	116635.60
1999	114589.90	96110.96	108898.60	118559.94
2000	116278.61	97166.36	110387.16	120422.75
2001	117909.34	98167.46	111817.36	122223.54
2002	119481.90	99114.65	113189.19	123962.09
2003	120996.36	100008.40	114502.89	125638.40
2004	122453.00	100849.44	115758.90	127252.73
2005	[illegible]	[illegible]	[illegible]	[illegible]

SOURCE OF HISTORICAL DATA: U.S. Department of Commerce, Statistical Abstracts, 1979.

FIGURE 7-2. FORECAST OF MERCHANT VESSELS OVER 100 TONS (CONT.).

EVENT NO.	YEAR/PROB	YRS TO FIRST IMPACT	YRS TO MAXIMUM IMPACT	MAXIMUM IMPACT	YRS TO STEADY STATE IMPACT	STEADY STATE IMPACT
RELATIVE IMPACT						
1	1990 0.25 2005 0.50	0	1	-15.0%	1	-15.0%
-.116E+06	AVERAGE SHIP SIZE INCREASES 15%					
3	1990 0.50 2005 0.75	3	5	-10.0%	5	-10.0%
-.109E+06	STRICTER MARINE REGULATIONS					
2	1990 0.25 2005 0.50	0	1	7.0%	1	7.0%
.541E+05	WORLD TRADE INCREASES 10% OVER HISTORICAL RATE					
4	1990 0.20 2005 0.40	3	5	15.0%	5	15.0%
.230E+05	OIL SPILLS AND OTHER ENVIRONMENTAL CONCERNS LEAD TO SMALLER SHIPS					

FIGURE 7-2. FORECAST OF MERCHANT VESSELS OVER 100 TONS (CONT.).

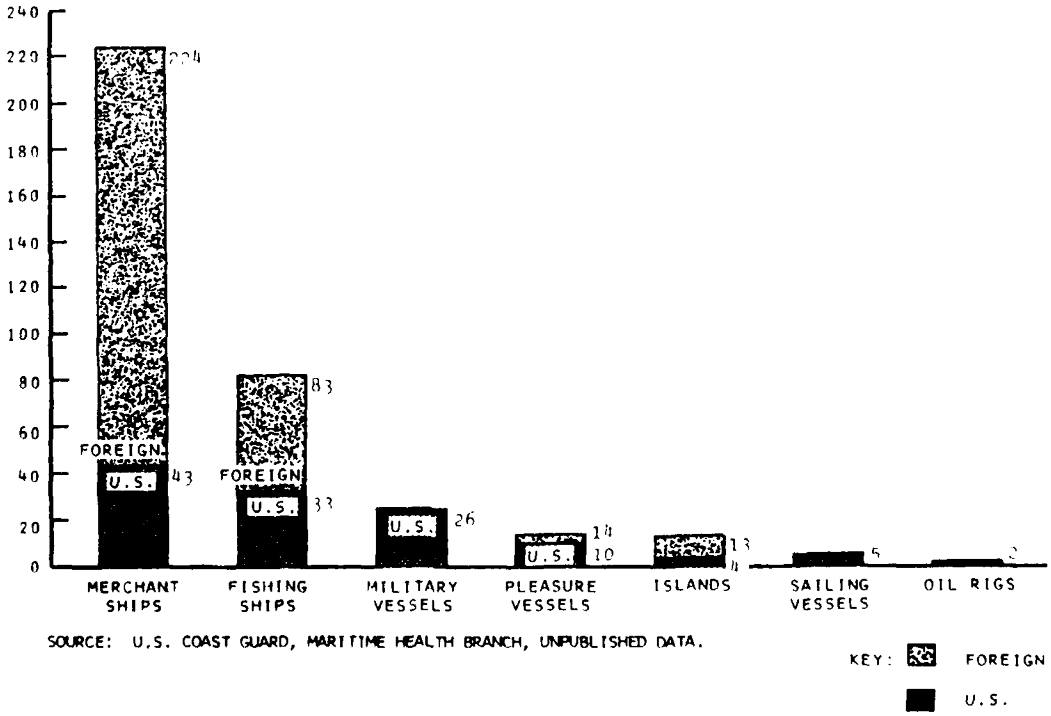


FIGURE 7-3. REQUESTS FOR MEDEVAC MEDICAL ASSISTANCE BY TYPE OF VESSEL, FEB/NOV 1979.

AD-A089 995 FUTURES GROUP GLASTONBURY CT F/G 6/5
A STUDY TO DETERMINE THE EVOLUTION OF ADVANCES IN MEDICAL TECHN--ETC(U)
MAY 80 T J GORDON, L MASON, H TRUITT DOT-CG-906760-A
UNCLASSIFIED 448-103-05/01 USCG-D-40-80 NL

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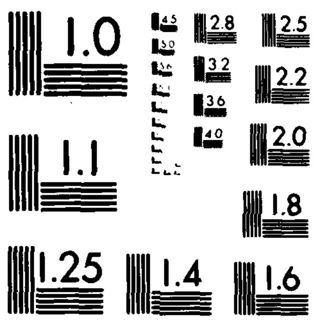

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

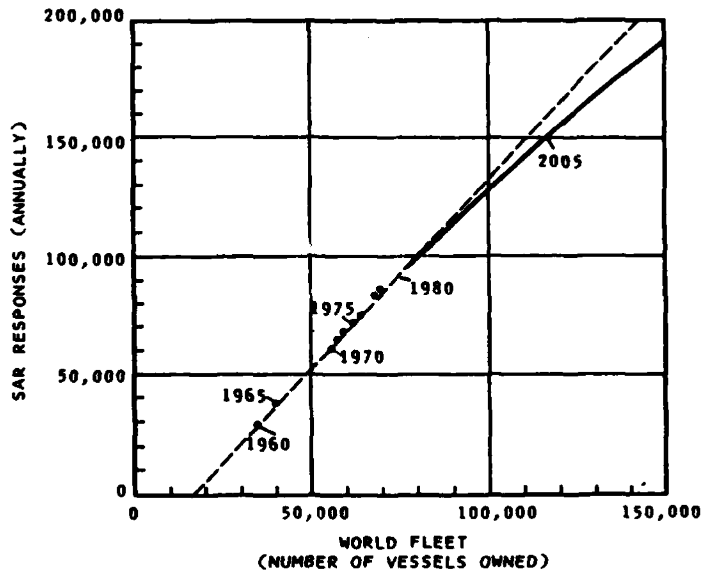

FIGURE 7-4. SAR RESPONSES VERSUS WORLD FLEET SIZE.

in the future, automation, improved inspection, earlier warning of adverse weather, and other such developments will tend to improve overall safety and diminish the frequency of emergencies. We therefore anticipate a diminishing rate of SAR missions as the world fleet continues to grow (solid line). Figure 7-5 projects SAR missions, based on the merchant fleet forecast (Figure 7-2) and the correlation between the number of vessels and SAR missions (Figure 7-4). From a current level of about 85,000 SAR responses per year, we expect the level to grow to a nominal value of 150,000 SAR responses per year by 2005. As before, the uncertainty in that forecast is rather high and extends from 130,000 to 166,000 responses per year.*

Medical support must, of course, be provided for these SAR missions. It is very difficult to forecast the exact nature of the medical emergencies between the present and the time 25 years from now. However, some clues may be gained by examining the causes of death and personnel injuries arising from accidents involving vessel casualties and other causes on commercial vessels. These data are presented in Figures 7-6 to 7-9. The kinds of medical emergencies that these accidents suggest include falls from vessels into water, exposure and asphyxiation, fractures, contusions, sprains, lacerations, burns and

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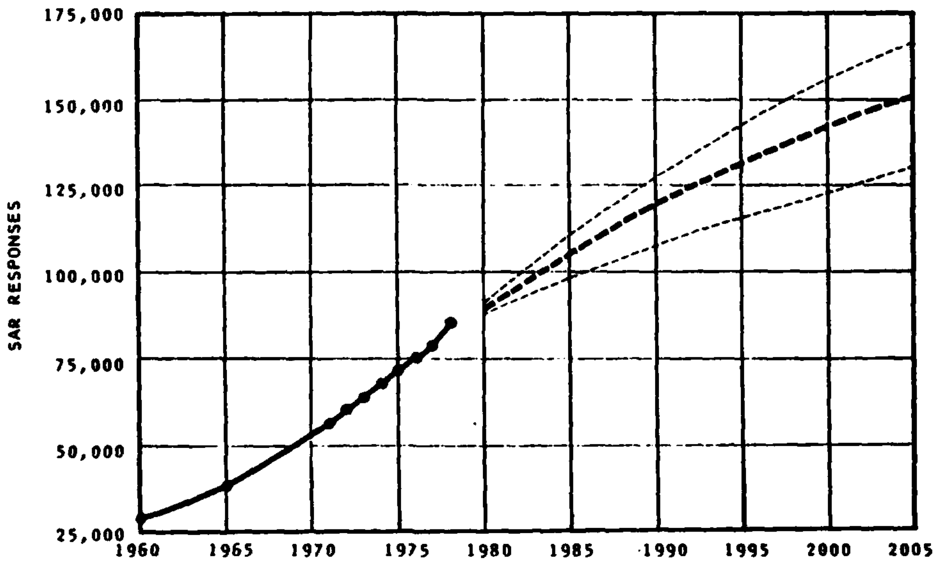
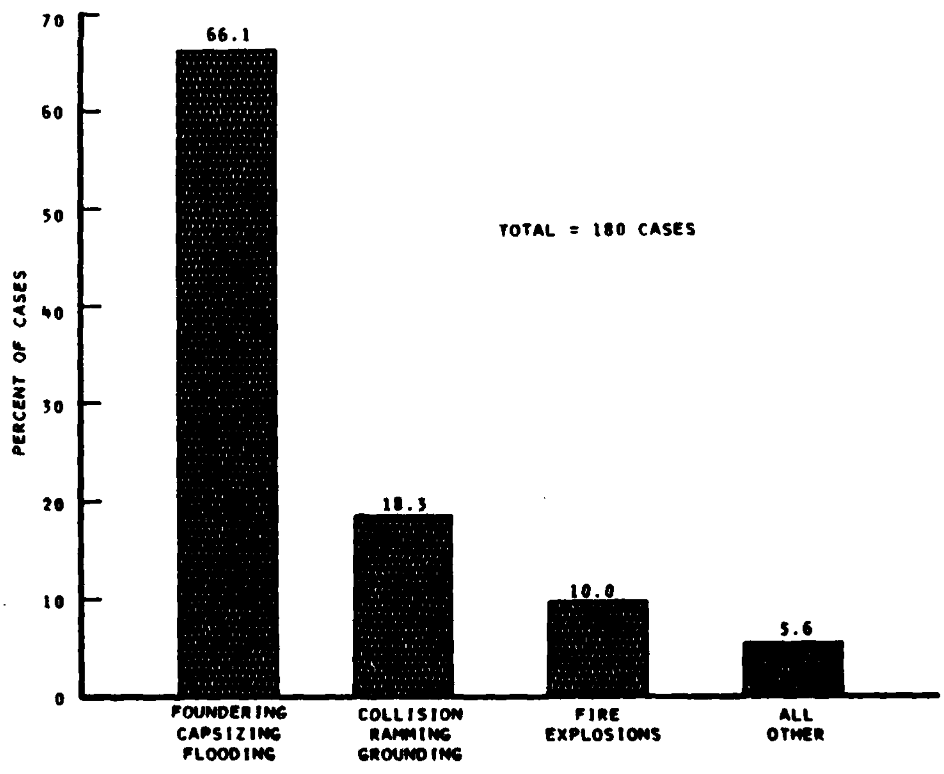
*Note: In discussions with the Maritime Administration of the Department of Commerce, it was suggested that the number of trips in major ports might provide a more valid correlation to SAR responses. However, data (available for calendar years 1970 through 1977) obtained from Waterborne Commerce of the United States, Department of the Army Corps of Engineers (Vicksburg, Miss.), indicate that the number of commercial trips declined 12 percent from 1970 to 1977 (and 6 percent from 1975 to 1977).



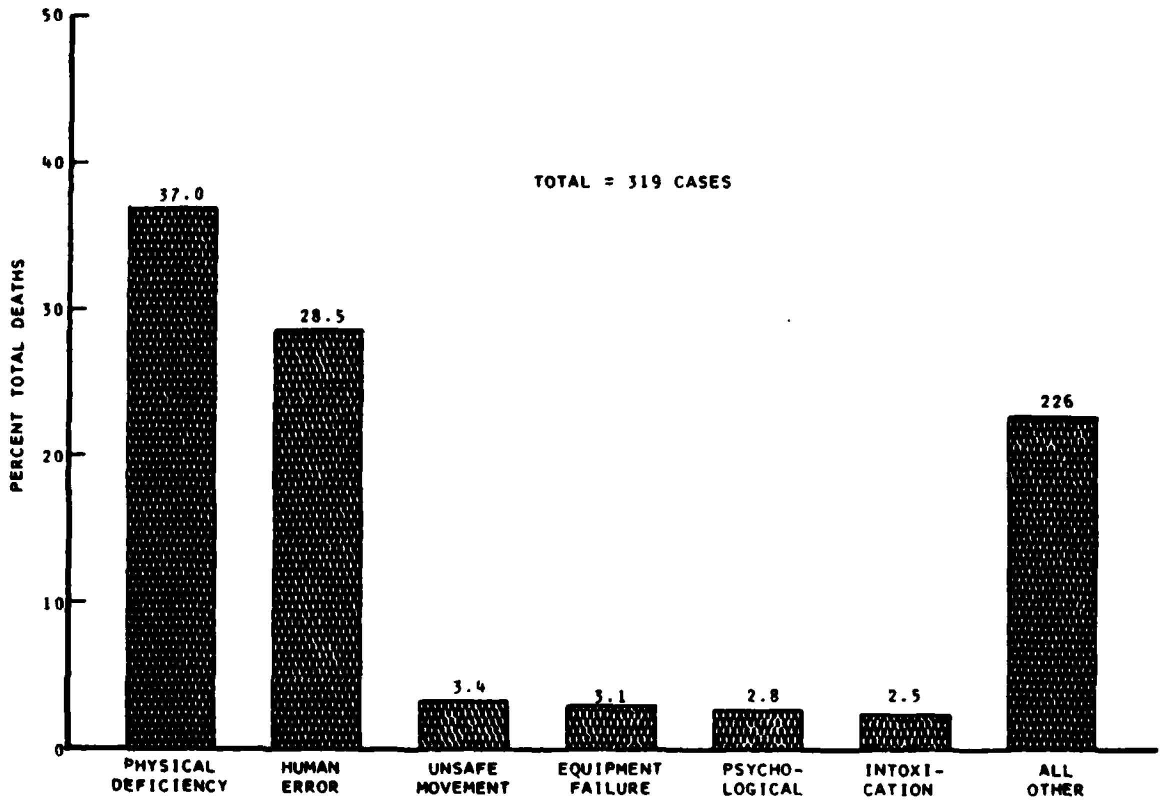
SOURCE OF HISTORICAL DATA: U.S. COAST GUARD, SERVICE-WIDE SEARCH AND RESCUE STATISTICS, FY-71-FY-75; BUDGET OF THE UNITED STATES GOVERNMENT--APPENDIX 1962-1989 (U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON DC).

FIGURE 7-5. NUMBER OF SAR MISSIONS.



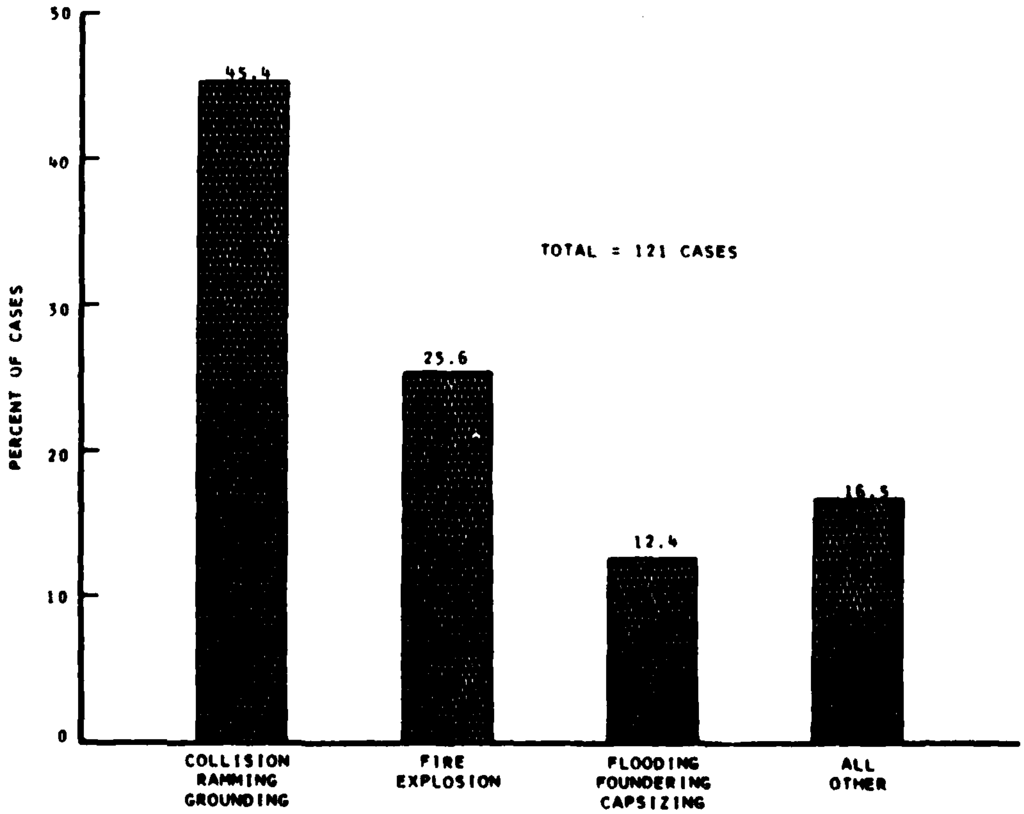
SOURCE: U.S. COAST GUARD, MARINE SAFETY STATISTICAL REVIEW, COMDINST M16700.2 (WASHINGTON, DC: 1 JANUARY 1979), P. II-5.

FIGURE 7-6. PERSONNEL DEATHS BY TYPE OF VESSEL CASUALTY, 1978.



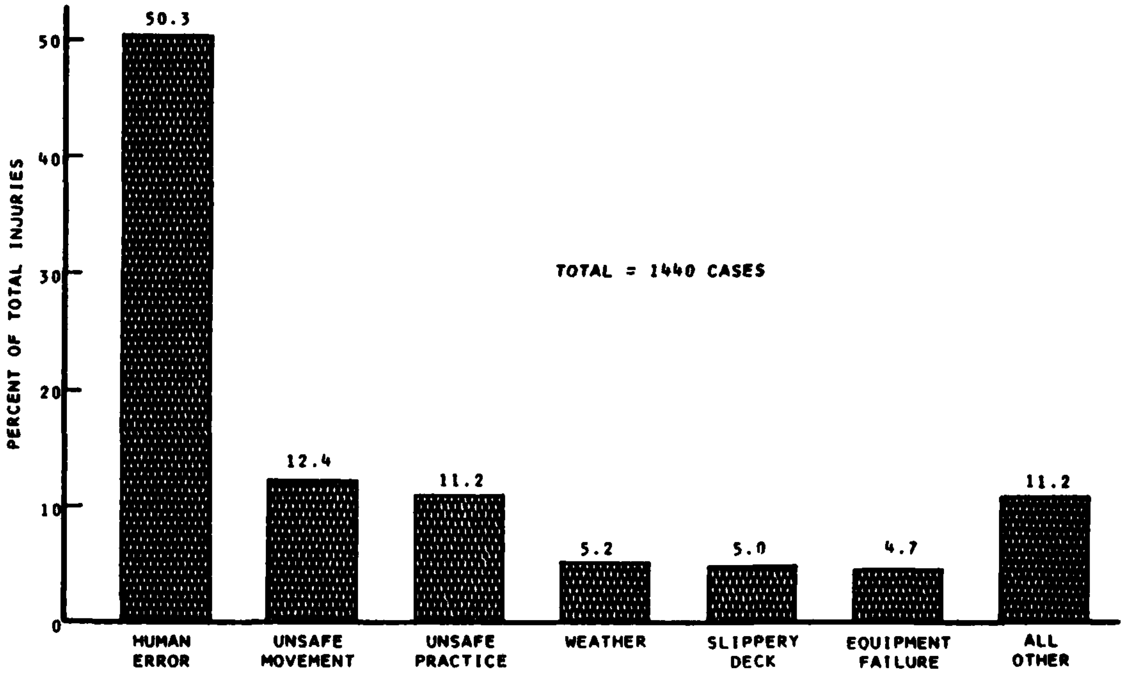
SOURCE: U.S. COAST GUARD, MARINE SAFETY STATISTICAL REVIEW, COMDINST M16700.2 (WASHINGTON DC: 1 JANUARY 1979), P. 11-8.

FIGURE 7-7. CAUSE OF DEATH ON COMMERCIAL VESSELS (NO VESSEL CASUALTY), 1978.



SOURCE: U.S. COAST GUARD, MARINE SAFETY STATISTICAL REVIEW, COMDINST M16700.2 (WASHINGTON, DC: 1 JANUARY 1979), P. 11-5.

FIGURE 7-8. PERSONNEL INJURIES BY TYPE OF VESSEL CASUALTY, 1978.



SOURCE: U.S. COAST GUARD, MARINE SAFETY STATISTICAL REVIEW, COMDINST M16700.2 (WASHINGTON DC: 1 JANUARY 1979), P. II-10.

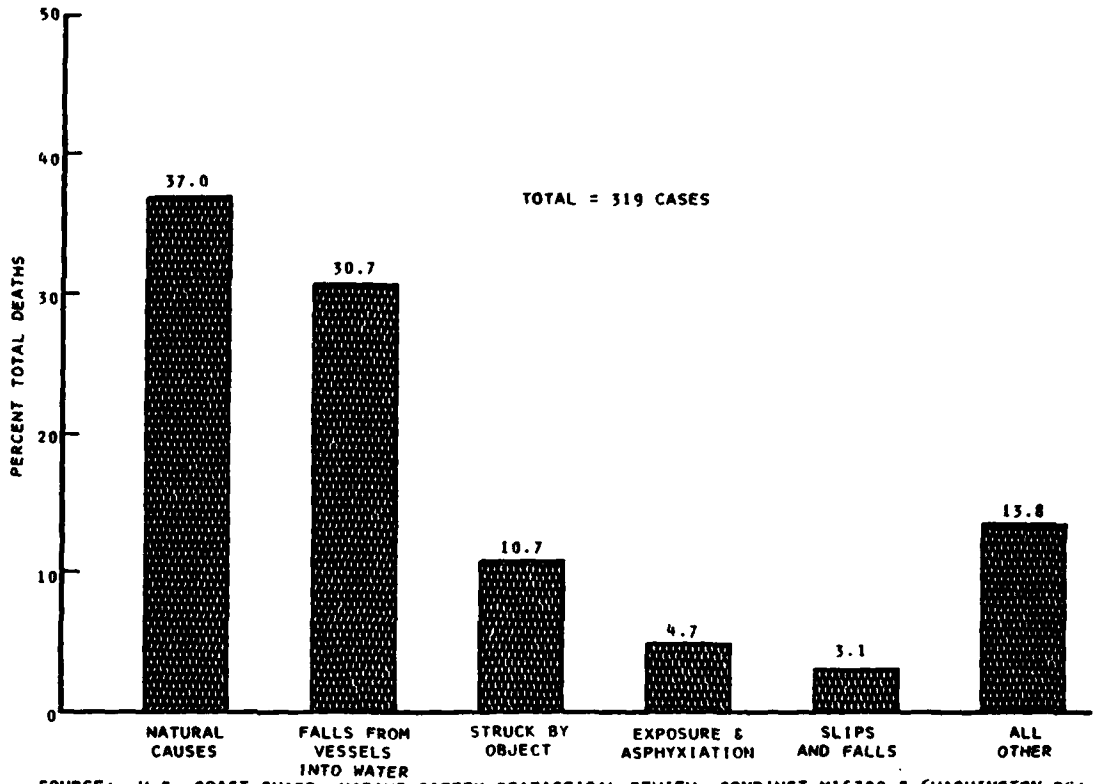
FIGURE 7-9. CAUSE OF PERSONNEL INJURIES ON COMMERCIAL VESSELS (NO VESSEL CASUALTY), 1978.

scalds, and death from natural causes. The data for 1978 are presented in Figures 7-10 and 7-11. As for illnesses, medical assistance and Medevac requests between the period February through November include the following:

Abdominal pains (2 DOA)	58	Lacerations	8
Arm/leg injuries	56	Unconscious (2 DOA)	7
Heart attacks (19 DOA)	32	Kidney stones	7
Appendicitis	28	Shock (1 DOA)	5
Head injuries (4 DOA)	26	Ulcers	5
Chest pains	18	Extremities in winch	4
Fall injuries (4 DOA)	13	Diabetic (2 DOA)	14
Internal bleeding	12	Collapsed lungs	3
Eye injuries	8		

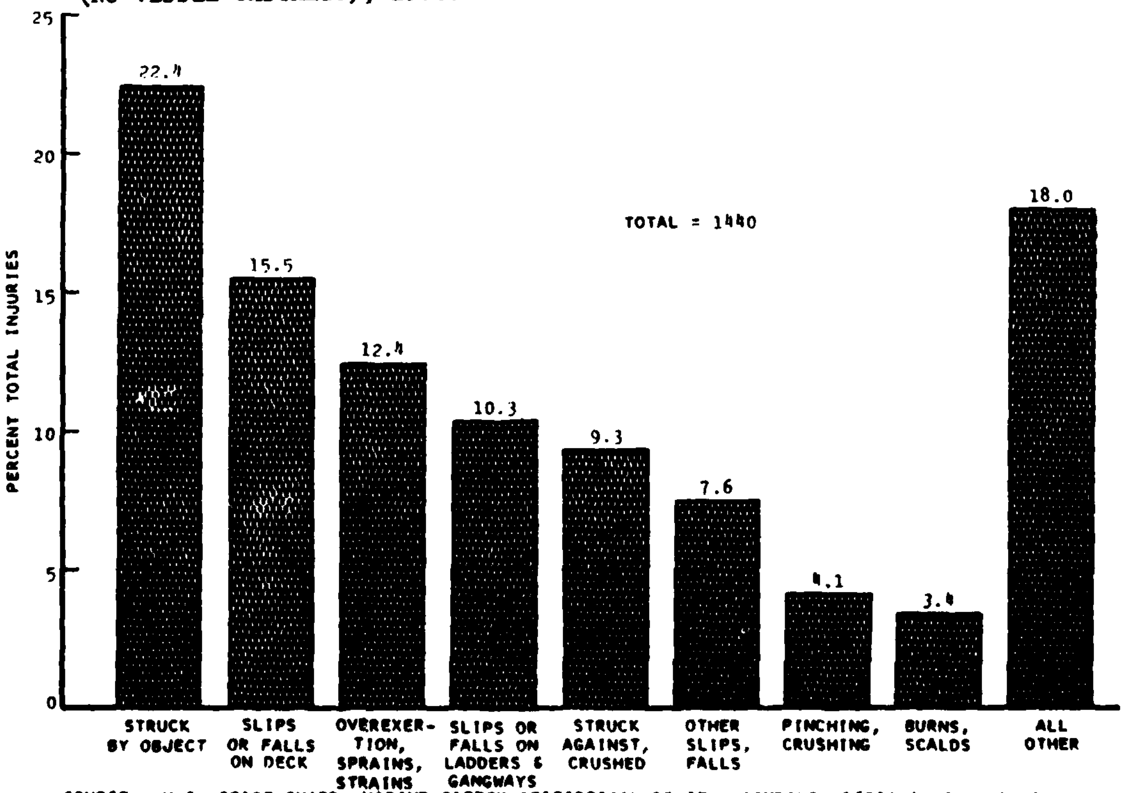
Also reported were strokes, hernia, fevers, broken ribs, apoplexy, emphysema, bends, asthma, and burns.

Will the mix of accidents and illnesses change over the next 25 years? Most probably. Because of advances in cardiovascular science, particularly



SOURCE: U.S. COAST GUARD, MARINE SAFETY STATISTICAL REVIEW, COMDINST M16700.2 (WASHINGTON DC: 1 JANUARY 1979), P. II-7.

FIGURE 7-10. NATURE OF PERSONNEL DEATHS ON BOARD COMMERCIAL VESSELS (NO VESSEL CASUALTY), 1978.



SOURCE: U.S. COAST GUARD, MARINE SAFETY STATISTICAL REVIEW, COMDINST 16700.2, (WASHINGTON DC: 1 JANUARY 1979), P. II-9.

FIGURE 7-11. NATURE OF PERSONNEL INJURIES ON COMMERCIAL VESSELS (NO VESSEL CASUALTY), 1978.

in diagnosis and therapy, we expect to see the frequency of heart attacks and strokes diminished. The diabetic emergencies present in the above list are also likely to be absent by 2005, since availability of insulin--probably produced through recombinant DNA processes in vitro--will be much greater and emergencies of this sort much less frequent. However, the preponderance of medical emergencies are injuries, and changes in the frequency of injuries depend on safety practices, equipment design, and equipment reliability. Overall, we would expect to see few changes in the nature of injuries resulting from accidents over the next few decades. (One exception is the possibility of an increased number of radiation injuries, should the use of nuclear-powered vessels become more widespread.)

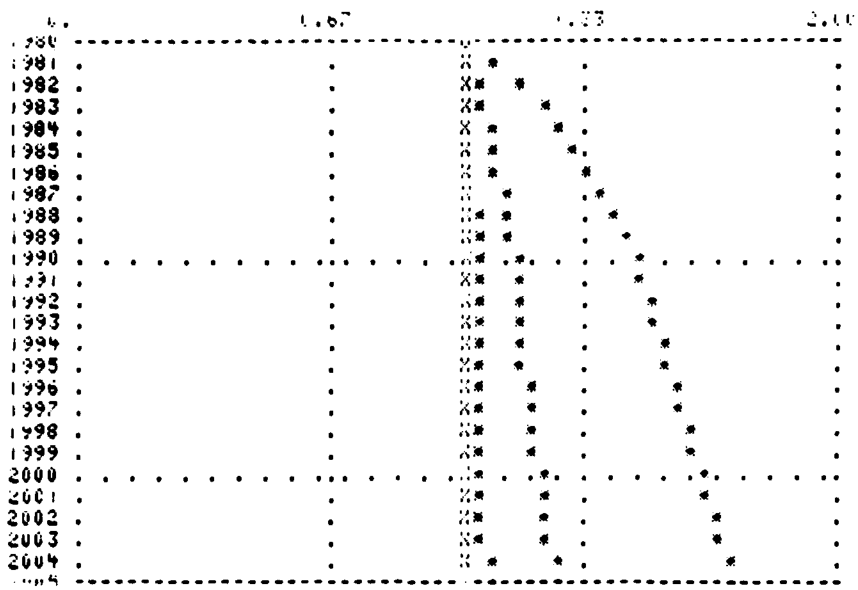
It is important to note that while distribution of accident-related injuries may be roughly the same in the future as it is at the present, the relative number of people exposed to situations in which such injuries might occur may well be reduced. We expect that shipboard automation will continue to advance rapidly; thus, the number of people required to operate a ship will be reduced. Earlier in this chapter we argued that the number of ships over 100 tons might grow from 69,000 in 1978 to 117,000 by the year 2005. We think it reasonable to expect that the number of people required to operate a ship will drop by about 20 percent over this time period as a result of rapidly increasing automation capability and diminishing automation costs. These factors have been synthesized in a TIA forecast in Figure 7-12, the index of medical support required for SAR missions.

Another dimension of medical emergency support relates to time for the delivery of services. Figure 7-13 shows the distribution of the time required to respond to a call for help in 1978. The average time reported was 8.51 hours, while the median value is somewhere between 4 and 6 hours. The response time can be expected to drop significantly as the result of several factors. First, as indicated in earlier chapters, we expect that some medical care will be delivered via radio telemetry, and the requirement to evacuate the patient will be reduced. Furthermore, as speed and range of helicopters increases, response time will also be reduced somewhat. In the period between February and November 1979, about half of all Medevac assistance was accomplished through helicopter evacuation.

Not only must the Coast Guard provide medical support for emergency situations, but it must also provide medical services for its military and civilian personnel. The number of personnel likely to be associated with the Coast Guard in the next 25 years is, of course, very difficult to forecast. Figure 7-14 shows the number of military and civilian positions since 1960. Certainly over the next 25 years, the scope of Coast Guard missions will increase; for example, increased Coast Guard support will be required as a result of the use of artificial islands, the growing number of oil rigs, the increasing number of pleasure vessels, the growing number of merchant ships, etc. However, there is reason to expect that these future missions can be performed with increased productivity; some of the missions may be performed without additional personnel at all as a result of the introduction of unmanned systems.* Therefore, in projecting the future number of military and civilian positions, we have simply assumed a continuation of historical

*T. J. Gordon et al., A Morphological Analysis of Unmanned Vehicles (Glastonbury CT: The Futures Group, Inc., 1978).

HISTORICAL DATA = 0
CALCULATED DATA = X
TIA FORECAST = *
CONFIDENCE PERCENTILES = 25 AND 75



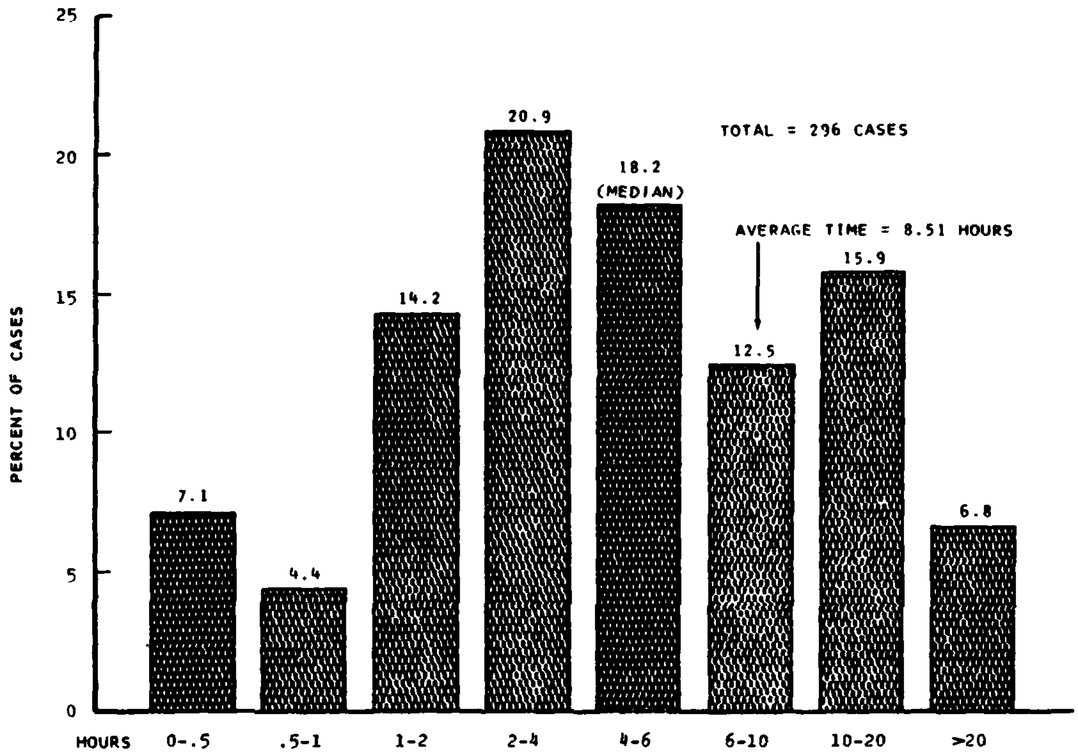
EVENT NO.	YEAR/PROB / RELATIVE IMPACT	YRS TO FIRST IMPACT	YRS TO MAXIMUM IMPACT	MAXIMUM IMPACT	YRS TO STEADY STATE IMPACT	STEADY STATE IMPACT
4	1990 0.75 2005 0.95 -1.24 REMOTE MEDICINE VIA TELEMETRY	0	10	-10.0%	10	-10.0%
1	1990 0.15 2005 0.50 -1.12 NUMBER OF PERSONS REQUIRED TO OPERATE A SHIP DROPS BY 25%	0	1	-20.0%	1	-20.0%
3	1990 0.25 2005 0.50 -0.146 SOME CRITICAL DISEASES ARE NO LONGER A CHRONIC OR ACUTE PROBLEM	0	10	-3.0%	10	-3.0%
2	1990 0.35 2005 0.75 5.90 NUMBER OF SHIPS INCREASES BY 59%	0	1	59.0%	1	59.0%

FIGURE 7-12. TREND IMPACT ANALYSIS: INDEX OF MEDICAL SUPPORT REQUIRED FOR SAR MISSIONS.

TREND IMPACT ANALYSIS

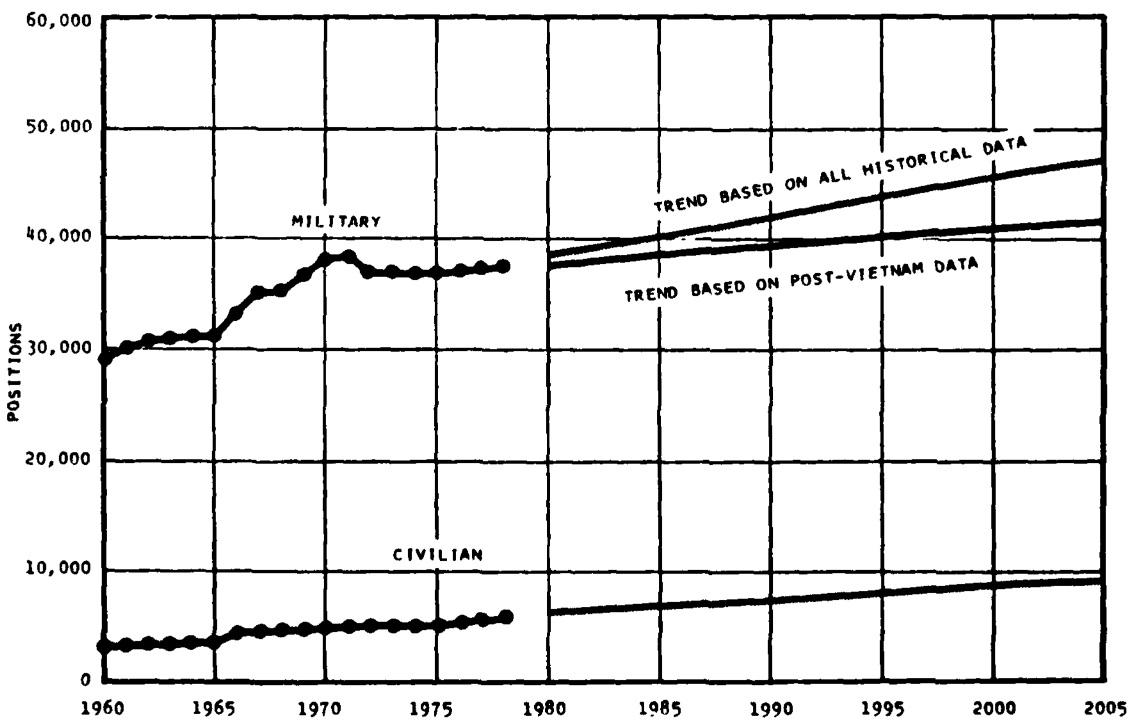
YEAR	HISTORY/ BASELINE	*** LOWER	FORECAST CENTER	*** UPPER
1970	1.00			
1980	1.00			
1981	1.00	0.99	1.01	1.06
1982	1.00	0.99	1.02	1.14
1983	1.00	0.99	1.04	1.19
1984	1.00	1.00	1.05	1.24
1985	1.00	1.00	1.07	1.28
1986	1.00	1.01	1.08	1.31
1987	1.00	1.01	1.09	1.35
1988	1.00	1.02	1.11	1.38
1989	1.00	1.02	1.12	1.41
1990	1.00	1.03	1.13	1.43
1991	1.00	1.03	1.13	1.46
1992	1.00	1.02	1.14	1.47
1993	1.00	1.02	1.14	1.49
1994	1.00	1.02	1.15	1.50
1995	1.00	1.02	1.15	1.52
1996	1.00	1.02	1.16	1.54
1997	1.00	1.02	1.17	1.56
1998	1.00	1.02	1.17	1.57
1999	1.00	1.03	1.18	1.59
2000	1.00	1.03	1.19	1.61
2001	1.00	1.04	1.20	1.63
2002	1.00	1.04	1.21	1.65
2003	1.00	1.05	1.22	1.66
2004	1.00	1.06	1.23	1.68
2005	1.00	1.06	1.24	1.70

FIGURE 7-12. TREND IMPACT ANALYSIS: INDEX OF MEDICAL SUPPORT REQUIRED (FOR SAR MISSIONS) (CONT.).



SOURCE: U.S. COAST GUARD, MARITIME HEALTH BRANCH, UNPUBLISHED DATA.

FIGURE 7-13. RESPONSE TIME BETWEEN CALL AND ARRIVAL OF HELP (FEBRUARY THROUGH NOVEMBER, 1979).



SOURCE OF HISTORICAL DATA: BUDGET OF THE UNITED STATES--APPENDIX, 1962-1980 (WASHINGTON, DC: U.S. GOVERNMENT PRINTING OFFICE).

FIGURE 7-14. MILITARY AND CIVILIAN POSITIONS.

trends of the past 20 years. These extrapolations are also shown in Figure 7-14. Under these assumptions, the number of military positions is expected to reach approximately 46,000 (42,000 if just the post Vietnam trend is followed) and the number of civilian positions approximately 9,300 by 2005.

The amount of medical support required, however, may not be proportional to this slow increase. The previous chapters of this report, particularly Appendix A, presented ideas about the changing nature of the quality of medicine which will be available and delivered over the next 2 decades. From a quantitative standpoint, the Coast Guard should expect that people will be living longer and that an increasing percentage of retirees will reach old age. Although the number of people over 65 years of age represents only about 10 percent of the U.S. population today, the use of health facilities, personnel, and pharmaceuticals is twice as high. Persons 65 and over account for more than three quarters of all physician's business, for arteriosclerosis and congestive heart failure. This small population group represents about half of all visits for diabetes, arthritis, hypertension and diseases of the blood.

Elderly persons are not only more likely to receive treatment for these chronic disorders, but treatment for acute illnesses is prevalent in this age group as well. Numerous physician visits for upper respiratory infections, bronchitis, cystitis, and infective and parasitic diseases lead to substantial use of antibiotics in this age group.

In 1980 there will be approximately 9½ million persons aged 75 and over. By the year 2000, the number of persons in this age group will increase by more than 50 percent.

Figure 7-15 presents an index of medical support required for routine care of military, civilians, and retirees. It is parallel to the chart mentioned previously (Figure 7-12) indicating medical support required for SAR emergencies. In this instance, we considered military and civilian personnel increases, increases in the number of retirees over age 65, efficiency improvements as the result of automation, the disappearance of some diseases as chronic or acute problems requiring medical attention, and improved diagnostic techniques--particularly for cancer, heart disease, and stroke. (Our reasoning in this last instance is that improved diagnostic cechniques will inevitably result in an increase in the discovery rate of people who have medical problems; therefore, improved diagnostic techniques result inevitably in an increase in the medical support required.)

The results of our Trend Impact Analysis indicate the index of medical support for routine care of military, civilian, and retirees will increase from its present level by 40 percent by the year 2005 (although this increase ranges from 29 to 78 percent over the interquartile confidence interval).

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HISTORICAL DATA = O
 CALCULATED DATA = X
 TIA FORECAST    = *
 CONFIDENCE PERCENTILES =  25 AND 75
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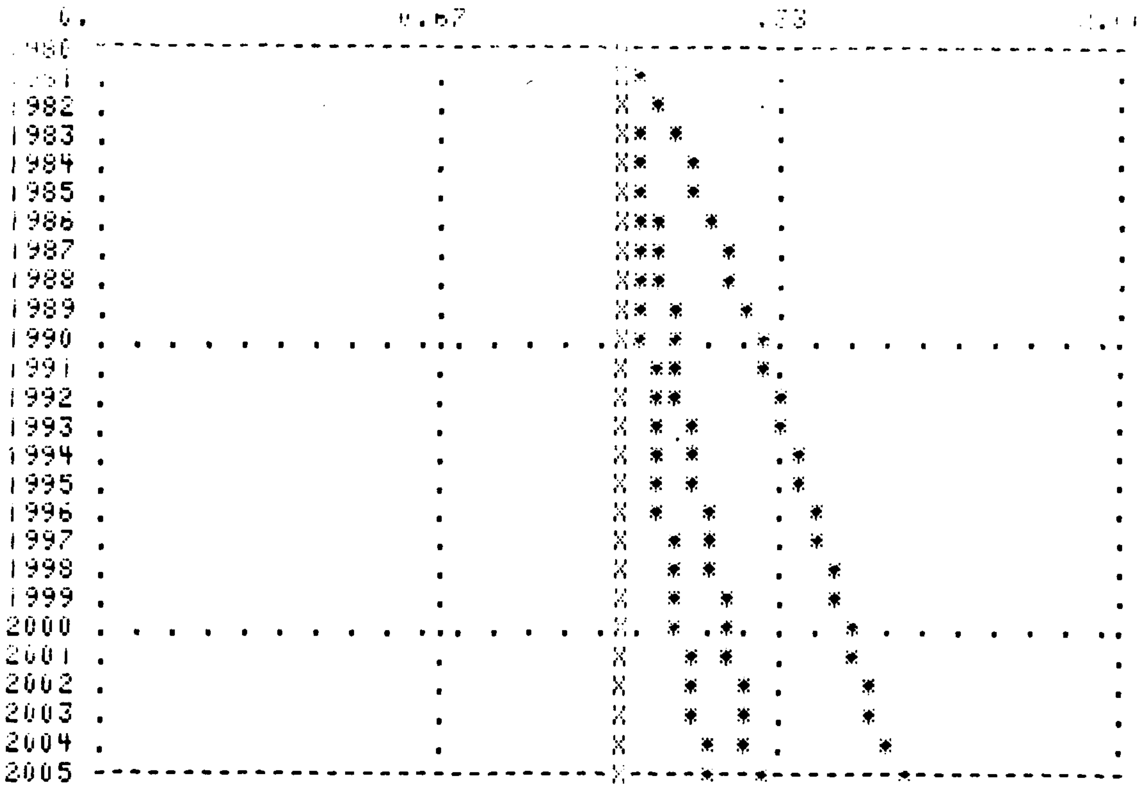


FIGURE 7-15. TREND IMPACT ANALYSIS: INDEX OF ROUTINE MEDICAL SUPPORT: MILITARY, CIVILIANS, & RETIREES.

In our analysis of the effect of future medical developments on the Coast Guard, we produced two additional forecasts:

- Medical expenditures

- Number of medical personnel.

These forecasts are presented in Figures 7-16 and 7-17.

EVENT NO.	YEAR/PROB RELATIVE IMPACT	YRS TO FIRST IMPACT	YRS TO MAXIMUM IMPACT	MAXIMUM IMPACT	YRS TO STEADY STATE IMPACT	STEADY STATE IMPACT
3	1990 0.75 2005 0.95 -1.24	0	10	-10.0%	10	-10.0%
	EFFICIENCY IMPROVES WITH AUTOMATION IMPROVEMENTS					
4	1990 0.25 2005 0.50 -0.146	0	10	-3.0%	10	-3.0%
	SOME CRITICAL DISEASES ARE NO LONGER A PROBLEM (CHRONIC OR ACUTE					
5	1990 0.75 2005 0.95 0.732	0	5	5.0%	5	5.0%
	IMPROVED DIAGNOSTIC TECHNIQUES FOR HEART DISEASE, STROKE, AND CANCER					
1	1990 0.25 2005 0.50 1.72	0	1	25.0%	1	25.0%
	NUMBER OF PERSONNEL INCREASES BY 25%					
2	1990 0.25 2005 0.85 2.27	0	2	25.0%	2	25.0%
	NUMBER OF PEOPLE 65 & OLDER INCREASES BY 12%					

FIGURE 7-15. TREND IMPACT ANALYSIS: INDEX OF ROUTINE MEDICAL SUPPORT: MILITARY, CIVILIANS, & RETIREES (CONT.).

Events reducing the need for medical services (and thereby having a negative impact on medical expenditures) include the understanding and application of psychological factors and their environmental interrelationships as well as the extensive use of physician-extenders. The application of computer technology and remote telecommunications to Coast Guard medicine will have a slight initial increase in medical expenditures followed by a reduction in expenditures as the benefits of these technologies are realized. The overall result is an initial increase followed by a very slight (if any) decrease.

TREND IMPACT ANALYSIS

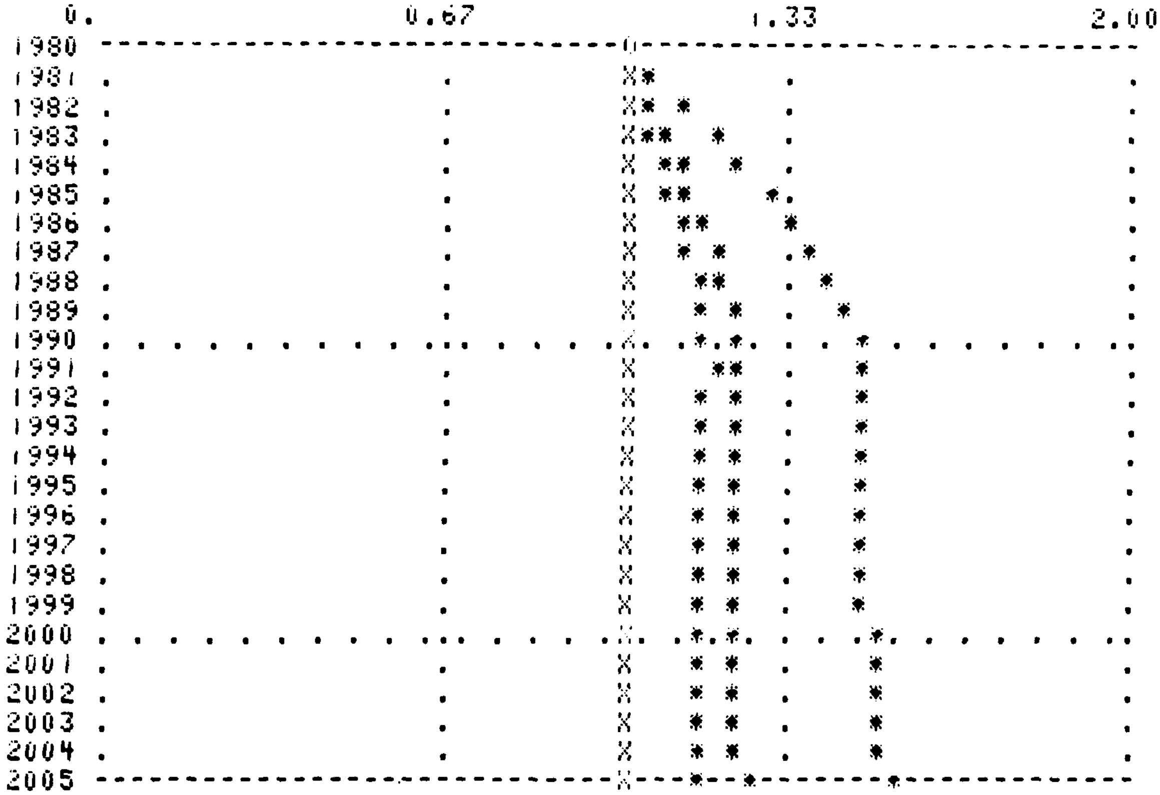
		***	FORECAST	***
YEAR	HISTORY/ BASELINE	LOWER	CENTER	UPPER
1970	1.00			
1980	1.00			
1981	1.00	1.00	1.01	1.03
1982	1.00	1.01	1.02	1.06
1983	1.00	1.01	1.03	1.10
1984	1.00	1.02	1.04	1.13
1985	1.00	1.03	1.05	1.15
1986	1.00	1.03	1.06	1.18
1987	1.00	1.04	1.07	1.20
1988	1.00	1.05	1.08	1.22
1989	1.00	1.05	1.09	1.24
1990	1.00	1.05	1.10	1.26
1991	1.00	1.05	1.11	1.28
1992	1.00	1.06	1.12	1.29
1993	1.00	1.06	1.13	1.31
1994	1.00	1.07	1.14	1.33
1995	1.00	1.07	1.15	1.35
1996	1.00	1.08	1.16	1.37
1997	1.00	1.09	1.17	1.38
1998	1.00	1.10	1.18	1.40
1999	1.00	1.11	1.19	1.42
2000	1.00	1.12	1.21	1.44
2001	1.00	1.13	1.22	1.46
2002	1.00	1.14	1.23	1.48
2003	1.00	1.15	1.24	1.50
2004	1.00	1.16	1.26	1.52
2005	1.00	[illegible]	[illegible]	1.53

FIGURE 7-15. TREND IMPACT ANALYSIS: INDEX OF ROUTINE MEDICAL SUPPORT: MILITARY, CIVILIANS, & RETIREES (CONT.)

The number of medical personnel, forecasted in Figure 7-17, is based on historical data for 1979 obtained from the Planning and Evaluation Staff of the Office of Health Services. The projection is based on the previous TIA forecasting indexes of search and rescue and routine medical support (Figures 7-12 and 7-15).

The events considered which might influence this trend included remote health care via telecommunications, improvements in emergency vehicles, understanding of environment/health/psychological states, emergency medicine recognized as a specialty, the use of physician-extenders, and improved diagnostic techniques. These events tended to have offsetting impacts resulting in a projection of virtually the same medical personnel requirements (again, assuming the proportion of medical personnel has remained constant).

HISTORICAL DATA = 0
CALCULATED DATA = X
TIA FORECAST = *
CONFIDENCE PERCENTILES = 25 AND 75



EVENT NO.	YEAR/PROB RELATIVE IMPACT	YRS TO FIRST IMPACT	YRS TO MAXIMUM IMPACT	MAXIMUM IMPACT	YRS TO STEADY STATE IMPACT	STEADY STATE IMPACT
4	1990 0.50 2005 0.75 -0.486	0	5	-3.0%	5	-5.0%
	PSYCHOLOGICAL FACTORS (MORALE BUILDING) IN HEALTH MAINTENANCE					
11	1990 0.25 2005 0.50 -0.320	0	3	-5.0%	3	-5.0%
	GREATER UNDERSTANDING OF THE PHYSICAL AND SOCIAL ENVIRONMENTS AND STATES OF HEALTH, AND A GREATER UNDERSTANDING OF PSYCHOLOGICAL STATES					

FIGURE 7-16. TREND IMPACT ANALYSIS: EXPENDITURES FOR MEDICAL SERVICES (INDEX).

EVENT NO.	YEAR/PROB RELATIVE IMPACT	YRS TO FIRST IMPACT	YRS TO MAXIMUM IMPACT	MAXIMUM IMPACT	YRS TO STEADY STATE IMPACT	STEADY STATE IMPACT
5	[illegible] 2005 0.95 -0.171 INCREASING COMPUTER APPLICATIONS TO A VARIETY OF DIAGNOSTIC ACTIVITIES	[illegible]	3	[illegible]	[illegible]	[illegible]
6	1990 0.75 2005 0.95 -0.171 EXTENSIVE REMOTE HEALTH CARE VIA TELECOMMUNICATIONS	0	3	3.0%	10	-3.0%
7	1990 0.75 2005 0.95 -0.156 EXTENSIVE USE OF PHYSICIAN EXTENDERS	0	3	-1.0%	3	-1.0%
8	1990 0.75 2005 0.95 -0.276E-01 COMPUTER DISPATCHING OF EMERGENCY MEDICAL AID	0	3	3.0%	6	-1.0%
9	1990 0.75 2005 0.95 0.389E-04 ADVENT OF WIDE VARIETY OF PORTABLE MEDICAL INSTRUMENTS, INCLUDING FLUOROMETERS FOR DETERMINING PRESENCE AND LEVELS OF CONTAMINATING MATERIALS, E.G., LEAD IN BLOOD STREAMS AND PORTABLE CLINICAL ANALYZERS	0	5	2.0%	10	-1.0%
2	1990 0.50 2005 0.85 0.126 EQUIPMENT FOR ONGOING NONINVASIVE MONITORING OF NORMAL BIOLOGICAL PROCESSES	0	1	1.0%	1	1.0%
1	1990 0.50 2005 0.75 0.209 REGIMENS FOR LIFE-EXPECTANCY PROLONGATION AND AGING RETARDATION	0	5	2.0%	5	2.0%
10	1990 0.75 2005 0.95 0.439 FASTER, SAFER, MORE EFFICIENT AUTOMOTIVE AND AIRBORNE AMBULANCES	0	5	3.0%	5	3.0%

FIGURE 7-16. TREND IMPACT ANALYSIS: EXPENDITURES FOR MEDICAL SERVICES (INDEX) (CONT.).

EVENT NO.	YEAR/PROB RELATIVE IMPACT	YRS TO FIRST IMPACT	YRS TO MAXIMUM IMPACT	MAXIMUM IMPACT	YRS TO STEADY STATE IMPACT	STEADY STATE IMPACT
3	1990 0.75 2005 0.95 0.750	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	ONGOING REAL TIME UPDATING OF ALL PERSONNEL MEDICAL RECORDS					
12	1990 0.50 2005 0.75 4.16	0	1	35.0%	1	35.0%
	THE NUMBER OF COAST GUARD PERSONNEL INCREASES BY 35%					

TREND IMPACT ANALYSIS

YEAR	HISTORY/ BASELINE	*** LOWER	FORECAST CENTER	*** UPPER
1970	1.00			
1980	1.00			
1981	1.00	1.00	1.01	1.05
1982	1.00	1.01	1.03	1.11
1983	1.00	1.03	1.06	1.17
1984	1.00	1.06	1.09	1.22
1985	1.00	1.08	1.11	1.26
1986	1.00	1.10	1.14	1.30
1987	1.00	1.11	1.16	1.34
1988	1.00	1.13	1.18	1.37
1989	1.00	1.14	1.20	1.40
1990	1.00	1.15	1.21	1.43
1991	1.00	1.16	1.22	1.45
1992	1.00	1.15	1.22	1.45
1993	1.00	1.15	1.22	1.45
1994	1.00	1.14	1.21	1.45
1995	1.00	1.13	1.20	1.45
1996	1.00	1.13	1.20	1.45
1997	1.00	1.12	1.20	1.45
1998	1.00	1.12	1.20	1.45
1999	1.00	1.12	1.20	1.46
2000	1.00	1.12	1.20	1.47
2001	1.00	1.13	1.21	1.47
2002	1.00	1.13	1.21	1.48
2003	1.00	1.14	1.22	1.49
2004	1.00	1.14	1.22	1.50
2005	1.00	1.14	1.23	[illegible]

FIGURE 7-16. TREND IMPACT ANALYSIS: EXPENDITURES FOR MEDICAL SERVICES (INDEX) (CONT.).

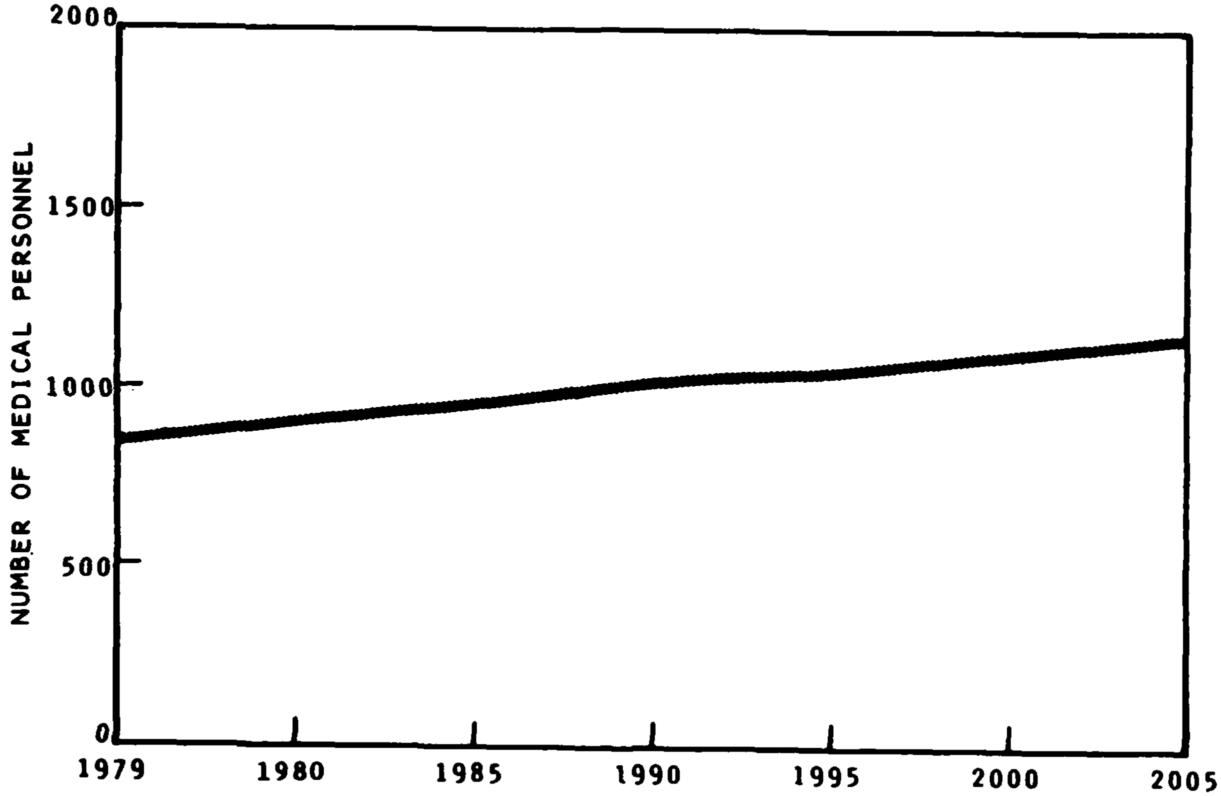


FIGURE 7-17. NUMBER OF COAST GUARD MEDICAL PERSONNEL.

The projections presented in the preceding figures graphically depict the anticipated values of each parameter over the next 25 years, as well as the 50 percent confidence interval. The most significant of these projections suggest a 25 percent increase in the costs of providing medical services (both operational and support) and an increase in the number of Coast Guard medical personnel by about one-third, between now and 2005.

Projections over such an extended time period, particularly in light of the limited data upon which these projections are based, should be viewed with those data limitations in mind. For example, in the absence of time-series data on medical support, index numbers were used; the assumption of stable trends implicit in the use of such baselines would introduce a bias should these assumptions be inaccurate. Recent Coast Guard improvements in data collection and record-keeping (as well as suggestions offered in this report) will provide the basis for testing these assumptions.

8. CONCLUSIONS AND RECOMMENDATIONS

1. Biomedical developments of the next 25 years will be profound and will have important consequences to morbidity and mortality. In particular, deaths due to heart disease, stroke, and possibly cancer will diminish during the eighties, thus increasing life expectancy and changing patterns of retirement.

2. In addition to biomedical developments, certain sociomedical developments are likely to be of importance including improved knowledge of the relationship of environmental and psychological factors and disease, growth in medical paraprofessions, and new licensing standards.

3. As far as the Coast Guard is concerned, most important medical developments that affect current or future Coast Guard missions are in the fields of

- emergency medicine
- remote telecommunications
- computer applications
- mobile laboratories.

4. Telemetry of data from emergency patients to remote physicians will be of increasing importance in the delivery of emergency health care sensing, and communications systems are improving in capability and decreasing in cost.

5. As use of remote monitoring and automated systems increases, personnel must be trained in new procedures related to sensing of biomedical information and transmission and executing physician's or computer-generated instructions.

6. Teleconsultation could be used by CG to make services of specialists either within the CG or from civilian facilities more readily available.

7. Medical record-keeping in the CG currently is not extensive. For example, it is difficult to reconstruct the number of deaths by cause or the types of medical emergencies encountered in search-and-rescue missions. We recommend that this system be improved since these data might lead to new strategies in search and rescue and improved epidemiological capability.

Better medical record-keeping seems likely to improve knowledge about levels of health and medical care in the CG, job-related illness and accidents, and search and rescue effectiveness (as mentioned above). Any decision to improve speed of delivery of emergency care, on-board instrumentation, sick bay equipment, consultation with specialists through teleconferencing, etc., must be based on information that is presently not available in detail. Therefore, we recommend that the medical information base be improved as a first step toward taking advantage of the new medical technologies described in this report.

A more advanced system of medical record-keeping would enable the Coast Guard to perform epidemiological investigations to identify their high-risk populations and high-risk assignments. The Coast Guard would then be able to initiate various preventive medicine programs based on current statistics. Viewing the Coast Guard medical mission as consisting of two parts--support of search and rescue (operational) and provision of baseline health services in support of USCG personnel, dependents, and retirees--we anticipate the following:

- The total number of Coast Guard medical personnel will increase 35 percent over the next 25 years as a result of growth of the world fleet, the increasing number of elderly, and improved diagnostic techniques.

- Medical costs are likely to increase over present levels by about 25 percent over this period as a result of the use of new equipment, more advanced ambulances and helicopters, life extension technologies, and the use of computers in diagnosis and record-keeping.

It is worthwhile to note that significant advances have taken place in the data collection and record-keeping activities of the Coast Guard. Due to these advances, it is believed these recommendations will find a receptive environment. Specific recommendations (e.g., including the addition of "Type of Medical Assistance Required" and "Degree of Severity" data in the "Case Data Section" of the "SAR Incident Summary" mentioned in Chapter 4) have been based on the most current information available.

8. While more problematic it seems likely that new medical capabilities will give rise to new Coast Guard missions based on these capabilities:

- Screening individuals entering or approaching the United States to determine whether they possibly carry dangerous organisms and to develop countermeasures.

- Medical and psychological factors will be considered in making personnel assignments; this matching will also include sensitive analysis of the physical and social environment into which people are placed. This notion of matching may give use to new specializations that have the responsibilities of supervising this person-to-environment match.

9. The Coast Guard should perform a comparative study of existing automated medical record-keeping systems to produce a plan for the introduction of such systems into the Coast Guard.

10. A number of potential new medical developments are anticipated that will aid the Coast Guard and require initial planning. Among the most attractive of these systems are

- computerized clinical support; the Coast Guard should consider developing algorithms as a precursor to implementing such systems.

- computer-aided instruction (CAI), particularly for courses in CPR and addressing other recurring problems.

- as mentioned earlier, automation of medical records.

- telecommunications for remote transmission of medical data.