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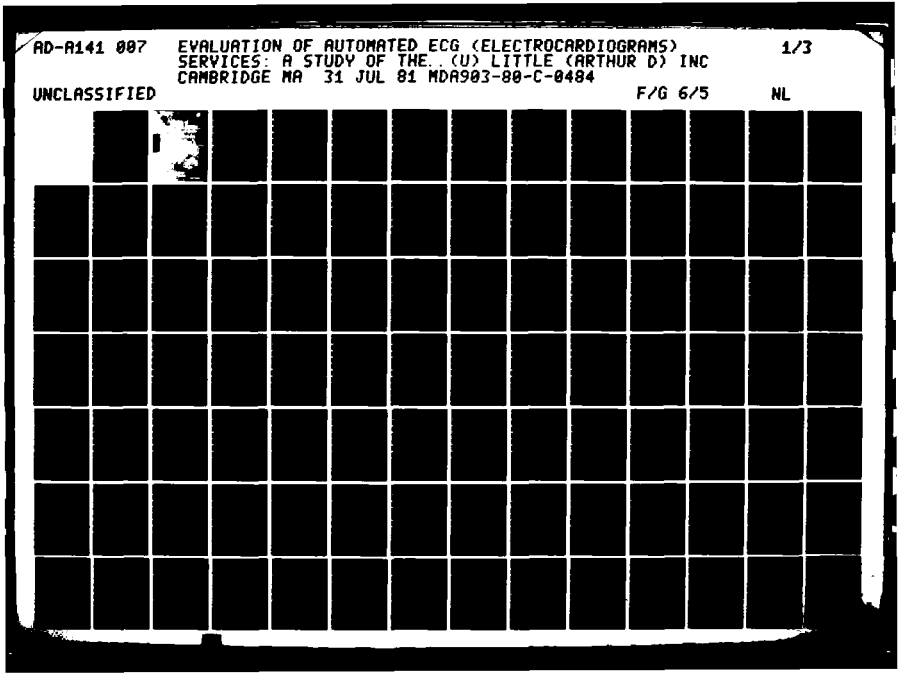

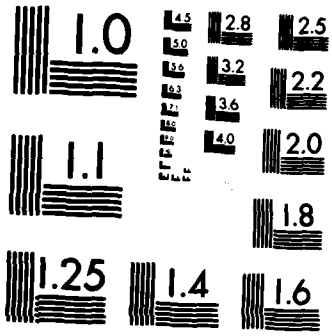

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Under sponsorship of the TRIMIS Program Office, a computer system for analysis of electrocardiograms was installed at 18 medical treatment facilities in the So. California area. The computer system, CAPOC, was the subject of this evaluation of the costs and effectiveness of ECG services before and after automation. This report outlines the evaluation process and presents our findings.

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EVALUATION OF AUTOMATED ECG SERVICES:

A STUDY OF THE COSTS AND BENEFITS OF CAPOC

IN THE SOUTHERN CALIFORNIA AREA

Prepared for

TRIMIS Program Office
6917 Arlington Road
Bethesda, Maryland 20014

Under

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By

Arthur D. Little, Inc.
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SUMMARY AND CONCLUSIONS
EVALUATION OF AUTOMATED ECG SERVICES

I. SUMMARY

Under sponsorship of the Tri-Service Medical Information Systems (TRIMIS) Program Office (TPO), a computer system for analysis of electrocardiograms (ECGs) was installed at 18 Medical Treatment Facilities (MTFs) in the Southern California area. The objective of the automated ECG system is to improve cardiac diagnosis and treatment in the military health care system by providing high-quality ECG analysis services, at a reasonable cost, to a large number of MTFs, many of which do not have cardiologists on their staffs.

Electrocardiograms are used to evaluate the cardiac status of a patient. The ECG can be taken inexpensively and with no risk to the patient (because the procedure is non-invasive). Therefore, the ECG is a basic tool in performing a cardiac evaluation. The interpretation of an electrocardiogram is usually combined with other test results and the findings of physical examination in order to assess the patient's cardiac status.

In the military, ECGs are used to screen healthy individuals to ensure that they are free of cardiac abnormalities, as a physical examination and other tests have suggested. For example, the ECG is a standard component of flight physical examinations. An ECG is also used as a diagnostic tool. For instance, it is one of several tests used to evaluate whether a patient with chest pain has had a heart attack. It is also used to monitor progress in patients with known cardiac disease, such as in determining if a heart attack is resolving or if a new medication is effectively treating a cardiac problem.

Electrocardiograms for these various purposes are taken in all MTFs. Since one of the major uses of ECGs is the diagnosis and treatment of patients that are potentially critically ill, ECG interpretations must also be available in all MTFs. However, trained cardiologists are not available within the military to staff every MTF, and in some sites, no specialists in internal medicine are assigned either. Since these facilities

are often remote, civilian specialists may not be readily available. The automated ECG system, which links remote facilities with large hospitals that have specially-trained physicians on the staff and provides rapid access to cardiologist consultation, was installed to make ECG interpretations more readily available at these facilities.

The costs and effectiveness of ECG services have been evaluated in the 18 project sites before and after the automation of ECG services. The conclusion of the evaluation is that an automated system provides more cost-effective services than can be provided by manual methods.

The major benefits of automation are related to access to and efficiency and quality of ECG services:

- improved access at small medical treatment facilities to cardiologists,
- support to non-cardiologist physicians in reading electrocardiograms, and
- decreased time to receive an ECG interpretation at remote treatment facilities.

Other benefits include:

- increased availability of prior electrocardiograms for comparison with the current ECG,
- saved time in reading electrocardiograms,
- improved technical quality of the ECG tracing,
- increased legibility and consistency of the ECG report,
- fewer lost ECG tracings and reports, and
- improved accuracy of reading (especially for normal tracings).

The effectiveness of ECG services before and after automation was measured against service criteria related to the availability of ECG readers with specialized training, the time delay before receipt of ECG interpretations, and the availability of prior ECGs for comparison with a current ECG. When the computer system is fully operational, the portion of ECGs meeting effectiveness criteria in the smaller MFTs will have increased from 38 percent to 86 percent; in the larger MTFs effective ECG services will have increased from 56 percent of all ECGs to 75 percent.

The costs of providing ECG services in the 18 MTFs were analyzed for the manual ECG services and the automated system. These costs were divided by the number of ECGs meeting criteria for effective ECG services in order to calculate a cost per effective ECG. The cost per effective ECG decreases from $15 to $12 when the system is fully operational; the cost per ECG meeting preferred service criteria will decrease from $107 to $18.

Thus, automated ECG services do meet the objective of providing high-quality ECG services in all Medical Treatment Facilities.

II. INTRODUCTION

The computer system, which was the subject of this evaluation, is referred to as CAPOC (Computer Assisted Practice of Cardiology). It has one central computer (located at San Diego Naval Regional Medical Center), which is used to provide ECG interpretations for MTFs within the Southern California area. From remote sites, electrocardiograms (ECGs) are transmitted over telephone lines to the central system and an interpretation is performed by the computer, transmitted over the telephone lines, and printed out within about 15 minutes at the site where the ECG was taken. The computer-generated interpretations can also be confirmed by cardiologists at the central site and then returned.

The evaluation of the CAPOC system was designed to provide information for decisionmaking regarding purchase of additional systems for installation in other regions, to determine whether or not the system met its objective of providing high-quality, cost-effective ECG services, especially to small facilities without a cardiologist on the staff, and to identify changes that should be made to increase the effectiveness of the system, or lower its cost.

In this summary section, the methodology developed for use in the evaluation will be described and then information on the findings of the evaluation will be discussed. More comprehensive information on the evaluation approach, analysis techniques, and results of the study are contained in the following chapters of this final report.

III. EVALUATION APPROACH

The evaluation was designed to compare manual ECG services before automation with services provided after the CAPOC system had been implemented.

In order to determine whether the CAPOC system did improve ECG services, a definition of effective ECG services was required. This was accomplished by a consensus process involving ECG users in MTFs. Survey responses were obtained from 55 physicians, and the results were reviewed by a panel of nine internists, cardiologists, and ECG technicians, who set the final criteria.

The users who participated in the consensus process identified three essential attributes of effective ECG services:

(1) accuracy of the interpretation,

(2) turnaround time to receive the interpretation, and

(3) use of serial comparison with prior ECGs.

Based upon these attributes, they defined two levels of effective ECG services: what is typically required for the ECG to be useful in clinical management of patients (acceptable service) and what permits the maximum benefit from ECG information in clinical decisionmaking (preferred service). Together these service levels constitute what we will refer to as "effective" ECG services. The criteria for effective ECG services that were developed and used in this evaluation are shown in Table S-1.

The "quality" of ECG services, as measured against these criteria, was quantified for manual and automated ECG services. As an example, the criteria for turnaround time for routine inpatient ECGs are that: an ECG returned within 2 days is acceptable, and an ECG returned in 1 day is preferred. Therefore, routine inpatient ECGs not returned within 2 days were not counted as "effective" ECGs in the evaluation. ECGs returned within 2 days were counted as effective (if other service criteria were also met). If the ECG was returned within 1 day, it was counted as an ECG that met the preferred level of service.

TABLE S-1

EVALUATION CRITERIA FOR ECG SERVICES

Criteria for Acceptable Services

- In a manual reading system ECGs are read by a cardiologist or internist.
- In a computer-assisted reading system, abnormal ECG interpretations are reviewed by a cardiologist or internist; normal interpretations are reviewed by a corpsman, general pratitioner, internist, or cardiologist.
- ECG interpretations are acceptable if returned within the following times:
  - Routine Inpatient: 2 days
  - Pre-Operative: 1 day
  - Emergency: 30 minutes
  - Routine Outpatient: 3 days
  - Annual Physical: 7 days
- All abnormal ECGs receive a serial comparison

Criteria for Preferred Services

- In a manual reading system ECGs are read by a cardiologist;
- In a computer-assisted reading system, abnormal ECG interpretations are reviewed by a cardiologist; normal interpretations are reviewed by a corpsman, general practitioner, internist or cardiologist.
- ECG interpretations are preferred if returned within the following times:
  - Routine Inpatient: 1 day
  - Pre-Operative: 12 hours
  - Emergency: 15 minutes
  - Routine Outpatient: 30 minutes
  - Annual Physical: 2 days
- All abnormal ECGs receive a serial comparison

The cost of providing manual and CAPOC services was also computed and the cost to provide an ECG meeting the criteria for effective services was calculated. If the cost per effective ECG was lower with CAPOC, the system would be considered successful.

The data on baseline (manual) services were collected in the Fall of 1979. Data on CAPOC services were obtained in the Fall of 1980. To limit the cost of data collection, five sites were chosen as primary evaluation sites. These included the largest referral site in the region, a smaller referral hospital, a small branch clinic, a small remote branch hospital, and one small hospital not affiliated with a large referral center. The sites were chosen to be representative of the staffing patterns, patient populations, and ECG services found in the region. Information on ECG services was collected at the primary evaluation sites through on-site data collection, review of hospital and ECG department records, interviews with staff, and administration of a survey to ECG readers and users of ECG services.

Brief site visits were conducted to the remaining 13 secondary evaluation sites in the region in order to obtain information on manual and automated ECG services. In these site visits a description of the ECG process was obtained and estimates or data were obtained on the percentage of normal and abnormal ECGs processed, the turnaround time to receive an interpretation, and the training of ECG readers.

These data were then used to estimate effectiveness of services in the region with both manual and automated services and to determine the impact of CAPOC on the costs and effectiveness of services.

IV. EVALUATION FINDINGS

A. Summary Findings

The major finding of the CAPOC evaluation is that automated ECG services provide high-quality, cost-effective ECG services within the DoD health care system. In the Southern California area, the cost per effective ECG will decrease from $15 to $12 when CAPOC is fully operational. The cost per ECG meeting the preferred service levels will drop from $107 to $18. The greatest benefits from automation are realized at small MTFs.

For these sites, the CAPOC system:

- provides increased access to cardiologists, located primarily at large MTFs. (These cardiologists can either routinely review tracings or be asked to interpret a specific ECG.)
- supports non-cardiologists in reading normal electrocardiograms by providing a second opinion--the computer interpretation, and
- makes ECG interpretations available from outside the facility in minutes rather than days.

At the larger MTFs, CAPOC:

- increases access to prior electrocardiograms (which can be stored in the computer and printed out automatically), and
- reduces cardiologists' time required to interpret the electrocardiogram.

At all MTFs, CAPOC:

- improves the quality of ECG tracings, resulting in fewer repeat tracings or fewer ECGs that cannot be interpreted,
- increases the ease of reading and understanding interpretations (since they are printed rather than handwritten), and
- decreases the number of ECG tracings and interpretations lost, resulting in fewer patient recalls for repeat examinations.

There is another benefit, which, although difficult to quantify, is felt to be important: many physicians at San Diego NRMC believe that CAPOC improves the overall accuracy and consistency of ECG readings.

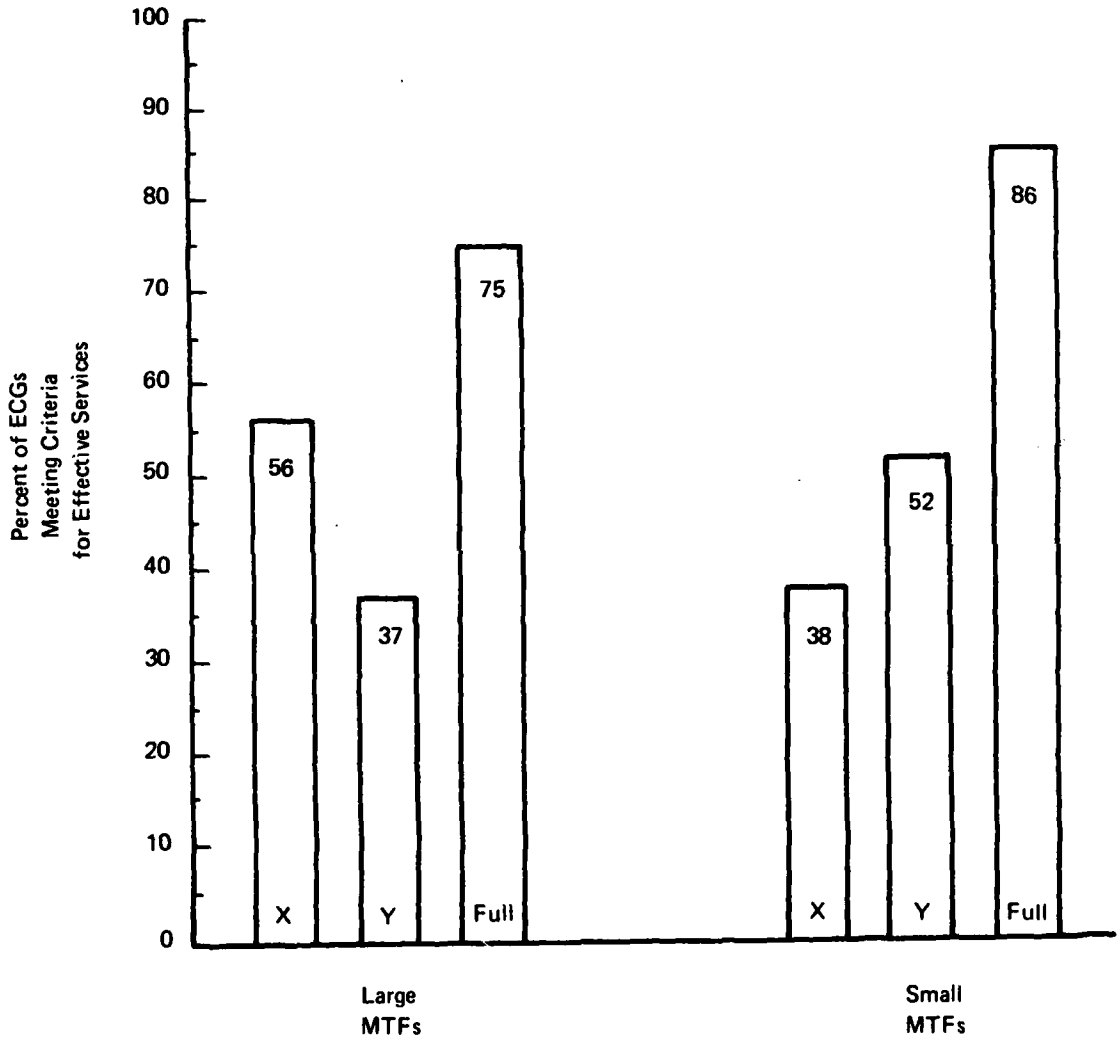
B. Measurement of CAPOC Impacts on Service Effectiveness

Table S-2 summarizes information on effectiveness of current and projected automated services for the 18 CAPOC sites in the Southern California area. Figure S-1 plots the change in service effectiveness for small and large MTFs.

TABLE S-2

EFFECT OF CAPOC ON EFFECTIVENESS OF ECG SERVICES IN THE SOUTHERN CALIFORNIA AREA

Service Effectiveness Measure	Number (percent) of ECGs		
	Manual Services (Best Estimate)	CAPOC Services (Fall 1980) (Best Estimate)	CAPOC Services Full Implementation
ECG Reader			
Acceptable	34,763 (43.5)	23,499 (31.1)	13,653 (18.1)
Preferred	33,317 (41.7)	43,885 (58.1)	60,029 (79.5)
Turnaround Time			
Acceptable	34,186 (42.7)	22,461 (29.7)	19,049 (25.2)
Preferred	28,328 (35.4)	27,855 (36.9)	47,343 (62.7)
Abnormals with Serial Comparison	13,674 (43.5)	6,306 (20.0)	23,046 (73.7)
Total Effective ECGs	40,282 (50.3)	31,332 (41.5)	59,171 (78.3)
Acceptable	34,743 (43.4)	20,247 (26.8)	20,872 (27.6)
Preferred	5,539 (6.9)	11,085 (14.7)	38,299 (50.7)



Note: Small MTFs are those with fewer than 100 beds and/or fewer than 200,000 outpatient visits per year.

FIGURE S–1 ECG SERVICE EFFECTIVENESS CHANGES AT LARGE AND SMALL MEDICAL TREATMENT FACILITIES.

Because of problems in interfacing equipment, delays in changes to the communications system, and the need to modify the computer software to permit automated storage and retrieval of ECGs by Social Security Number and Family Member Prefix Code, CAPOC was not fully implemented in the Fall of 1980 when evaluation data were collected. Where data were not available, the impacts of CAPOC at full implementation were projected on the basis of knowledge of the manual services, observation of the system's performance in other sites, and the program underway to maximize system effectiveness at all sites. More detailed information on the current level of implementation and service provided by CAPOC is contained in the last section of this summary. Implementation status at each site is discussed in Chapters 3 and 4 of this final report.

Baseline data on the volume of ECGs, the distribution of ECGs by interpretation, and the type of patients receiving ECGs, were not available for all facilities, and estimates by staff were used to characterize baseline services. More complete data were available after automation since workload information was collected by the system. The information on service effectiveness shown in Table S-2 is based upon our judgment of the best available data. However, since the assumptions made may have a large effect on the magnitude of predicted service improvements, a range of impacts has been calculated to examine the sensitivity of the evaluation results to various assumptions. These are included in Chapter 5 of this final report.

1. Accuracy of the Interpretation

The accuracy of an ECG reading is difficult to measure, since an ECG reading is truly an "interpretation" and often accuracy cannot be confirmed by other tests. Therefore, the training of the ECG reader was used in the evaluation criteria as an indicator of reading quality in the quantitative assessment of this service attribute. This analysis was supplemented by the opinions of users regarding the relative accuracy of CAPOC and manual ECG interpretations.

Table S-2 shows the quantitative analysis of the impact of CAPOC on this aspect of ECG reading in the Southern California area. When ECG services

in the Southern California area were provided in the manual mode, 42 percent of ECGs were read by a cardiologist (the preferred reader) and 85 percent were read by a cardiologist or internist (both effective readers according to the evaluation criteria). Lack of access to internists and cardiologists to read ECGs was a problem primarily at small and remote facilities. With manual services only 32 percent of ECGs in small MTFs[1] were read by a cardiologist and only 54 percent were read by a cardiologist or internist.

With CAPOC, the evaluation criteria specify that the second opinion provided by the computer reading makes any physician or corpsman an effective reader for a normal ECG. (This is consistent with the survey results discussed later.) The computer reading support, plus the increase in ECGs transmitted to larger facilities for reading, will result in an increase of 13 percentage points (from 85 percent to 98 percent) in the number of ECGs in the 18 CAPOC sites meeting the effective reader criteria when automated services are fully implemented. The increase in ECGs meeting the criteria for effective reader will be realized primarily in small MTFs.

Physicians at San Diego Naval Regional Medical Center involved with ECG services were asked to compare the accuracy of CAPOC and manual ECG reading. These physicians had the most experience with CAPOC since they read the largest number of ECGs and CAPOC capability had been available at San Diego NRMC for a full year when evaluation data were collected. Their responses regarding the relative accuracy of manual and computer-assisted reading are summarized in Table S-3. Of 29 physician readers, who expressed an opinion about the overall accuracy of computer-assisted interpretations, 23 (79 percent) believe that CAPOC ECG reading is at least as accurate as manual reading. For ECGs within normal limits, 30 of 31 physician readers reported that CAPOC was at least as accurate as manual reading, with 13 of those indicating that CAPOC was more accurate. For abnormal ECGs, the physicians' opinions concerning the accuracy of CAPOC and manual reading were divided, with some favoring one or the other for different types of abnormalities.

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[1] Facilities with fewer than 100 beds and/or fewer than 200,000 outpatient visits per year.

TABLE S-3

ACCURACY OF CAPOC COMPARED WITH MANUAL ECG INTERPRETATIONS--
OPINIONS OF PHYSICIAN RESPONDENTS

Type of ECG	Relative Accuracy of ECG Reading (Percent of Respondents)					
	CAPOC More Accurate or No Difference			Manual More Accurate		
	Users*	Readers*	All Respondents	Users	Readers	All Respondents
All ECGs	80	79	80	20	21	20
Normal ECGs	100	97	98	0	3	2
All Abnormal	71	60	64	29	40	36
Rhythm Abnormalities	57	50	52	43	50	48
Myocardial Infarctions	67	66	66	33	34	34
ST-T Wave Abnormalities	86	77	80	14	23	20
Hypertrophy	71	66	67	29	34	33
Conduction Abnormalities	64	62	63	36	38	37

*Users are physicians who order ECGs to be taken on their patients and/or interpret ECGs for their own patients. Readers are physicians who interpret ECGs for patients treated by others and/or check ECG interpretations done by others. The respondent sample included 70 physicians who had been on the staff at San Diego NRMC prior to the installation of CAPOC. The number of respondents expressing an opinion on each question varied slightly. The respondent base for each question included 29 to 31 physician reader and 14 to 15 physician users. Other respondents expressed no opinion or indicated they did not know.

In addition, most of the physician ECG readers at San Diego NRMC (24 of 34 who expressed an opinion) felt that the computer errors tended to be false-positive errors (calling a normal ECG abnormal) rather than false-negative errors. This is consistent with the reported experience with computer-assisted ECG reading elsewhere.[2]

2. Turnaround Time to Receive Interpretations

At sites lacking a specialized ECG reader, either the patient or the electrocardiogram must sometimes be sent to another facility to obtain an ECG interpretation. In the manual mode, ECGs were most commonly sent by surface or guard mail, read, and then returned. In most cases these ECGs failed to meet turnaround time criteria for effective services because the ECG interpretation was not received back for several days. Therefore, if an ECG from a small, remote MTF was read by an effective reader, it typically did not meet criteria for effective turnaround time.

With manual services, 11 percent of all ECGs taken in small facilities in the Southern California area did not meet the criteria for turnaround time. In the Fall of 1980 only 5 percent of ECGs in small facilities did not meet turnaround criteria. With full automation, this will increase to 6 percent.

3. Use of Serial Comparison with Prior ECGs

Serial comparison refers to comparing a current ECG with a prior one in order to identify changes that have occurred over time. Serial comparisons are performed both for hospitalized patients (e.g., to monitor progress in patients who have had heart attacks) and for outpatients to check on their cardiac status. A serial comparison can be a useful screening tool since it permits the physician to differentiate an actual abnormality from a variation in an ECG that is normal for a given patient (a normal variant). In the military health care system, some annual

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[2] A. D. Hagen and J. S. Alper, "Evaluation of Computer Programs for Clinical Electrocardiography." Circulation 51-52, Suppl. II-193, 1975.

physical examinations also include an electrocardiogram with a serial comparison with prior tracings.

Hospitals with a high volume of electrocardiograms typically store a duplicate copy of the electrocardiogram in a patient file in the ECG department. When a patient receives an ECG, the file of prior tracings is retrieved. In small facilities, the ECG copy in the medical record is often the only source of prior ECGs. The ECG service criteria specify that all abnormal ECGs should receive a serial comparison. Storage and retrieval of a large volume of ECGs is time consuming and often inaccurate since the patient may not remember having prior ECGs, the tracing may be misfiled, or the medical record may not be available. Therefore, automated storage and retrieval of ECGs could save technician time and increase the availability of prior tracings.

The feature of automated storage and retrieval of ECGs is not yet implemented on the CAPOC system at San Diego NRMC. When it is available, the number of abnormal ECGs in the Southern California area that receive a comparison with a prior tracing is expected to increase from 43 percent to 74 percent. The percentage of abnormal ECGs receiving a serial comparison will not reach 100 percent since patients receiving their first ECG in an MTF will have no prior ECG on file for comparison. This of course would also be true for a manual ECG process.

4. Impact on Service Effectiveness

The CAPOC system will have an impact on effectiveness of ECG services in all sites in the Southern California area; however, the most dramatic change in the level of service effectiveness will occur in small facilities that do not have cardiologists or internists on the staff (see Figure S-1). At five of 18 sites in the Southern California area, none of the baseline ECGs met criteria for effective services. At five other sites, less than 50 percent of the ECGs taken in the baseline period met effective service criteria. After automation, 86 percent of ECGs in small MTFs will meet all criteria for effective service. Because a large percentage of ECGs taken in these MTFs are normal and taken as part of routine examinations, the service requirements at these sites are different. With CAPOC providing

support to the non-cardiologist reader and the potential for rapid consultation with specialists, the effectiveness of ECG services will be higher in small MTFs than in large MTFs when CAPOC is fully operational. The CAPOC system clearly meets its objective of extending high-quality ECG services to MTFs without a cardiology staff.

C. Cost-Effectiveness of ECG Services

To be judged high-quality (or "effective") service, an electrocardiogram must meet all service criteria. As shown in Table S-2, 50 percent of all ECGs in the Southern California area met all criteria for effective services in the baseline period. With the CAPOC system, it is predicted that 78 percent of ECGs will meet all criteria for effective services. The change in ECGs meeting preferred service criteria will be greater: 7 percent of ECGs met preferred criteria with manual services and 51 percent will meet preferred criteria when the CAPOC system is fully implemented.

Hardware and communication costs associated with CAPOC, though partially offset by cost savings for labor and supplies, increased the cost of providing ECG services in the region by 21 percent. These costs are primarily for the computer hardware, analysis software, and telephone transmission of the ECGs. However, the percentage increase in effective services is greater than the percentage increase in the cost of automation. Thus, when total costs of providing ECG services are divided by the number of effective ECGs, the cost per ECG meeting the criteria for effective services will decrease from $15 to $12 due to the CAPOC system. The cost per ECG meeting the criteria for preferred ECG services will decrease from $107 to $18. Therefore, the conclusion of this evaluation of the CAPOC project is that: when fully implemented CAPOC will provide more cost-effective ECG services than were provided by manual methods.

D. Increased Satisfaction with ECG Services

Health care providers were surveyed at primary evaluation sites in order to assess their satisfaction with ECG services before and after automation. Physicians rated the following as the most important attributes to an effective ECG service:

- ability to obtain emergency ECG services 24 hours per day;
- rapid availability of emergency ECGs;
- access to ECGs in all treatment areas;
- accuracy, consistency, legibility, and completeness of interpretations;
- technical quality of the tracings;
- availability of prior tracings for serial comparison; and
- availability of ECG expertise for consultations.

In the baseline survey, physicians expressed some dissatisfaction in each of these areas. They were most dissatisfied with access to emergency ECG services and the availability of prior tracings for serial comparison.

The CAPOC system is designed to increase access to ECG interpretations; improve completeness, consistency, and legibility of interpretations; improve technical quality of tracings; and provide prior tracings for serial comparison. Therefore, satisfaction with ECG services is expected to improve when CAPOC is fully operational.

At San Diego NRMC, where physicians have had the most experience with the CAPOC system (except for the feature of automated storage and retrieval), ECG readers were asked for their overall assessment of the system. Of 45 respondents, 47 percent said they were extremely or very satisfied, another 42 percent were fairly satisfied with CAPOC as currently implemented, and only 11 percent were somewhat or very dissatisfied. Of physicians who only use ECG interpretations in patient care (not ECG readers), 30 percent were extremely or very satisfied, and 55 percent were fairly satisfied. Only 15 percent were somewhat unsatisfied, and none reported being very dissatisfied with CAPOC. Reasons for dissatisfaction were related to technical problems (outdated equipment) or

operational issues (unavailability of unconfirmed CAPOC interpretations to physician users) rather than the specific capabilities of the system.

V. IMPLEMENTATION STATUS IN THE SOUTHERN CALIFORNIA AREA

A. Current Status

Several factors have delayed full implementation of CAPOC in the Southern California area. The capability for automated storage and retrieval of ECGs needed to be adapted to the 11-digit patient identification system used in the military. Therefore, this feature of the system, which will facilitate use of serial comparisons, was not in use during Y Period data collection. Availability of automatic storage and retrieval will increase the effectiveness of services in 12 of the 18 sites in the region.

Technical problems in transmission to the central computer have been encountered in five sites. This has been attributed to the interfacing of some ECG carts with the CAPOC system and to communication problems. Many of the sites that have experienced continual transmission difficulties have delayed use of CAPOC until the problems can be resolved. At other sites use of CAPOC is intermittent.

ECG capture at three sites has been limited because CAPOC capability is not available in all areas where ECGs are taken. One other site has had maintenance difficulties with an old ECG machine. A total of five more ECG machines in the region would increase the percentage of ECGs affected by CAPOC.

Some change in department operations would also maximize the benefits of CAPOC. If unconfirmed computer reports for normal ECGs were returned with the ambulatory patients and abnormal ECGs for pre-operative patients were available as soon as they were read, the percentage of ECGs meeting criteria for effective turnaround time would increase. Programs are currently underway to solve implementation problems in the Southern California area in order to obtain maximum benefits from the system.

B. Achieving Full Implementation of CAPOC

During this evaluation, technical and operational changes were identified that would increase the benefits of the CAPOC system in the Southern California area:

- technical enhancements;
- better equipment availability and reliability;
- additional training in system use; and
- changes in operating procedures.

The major technical enhancement that will increase the system's cost effectiveness involves hardware and/or software modifications to provide capability for automatic storage and retrieval of ECGs. Two modifications are required: (a) the inclusion of patient name associated with Family Member Prefix and Social Security Number, and (b) automatic retrieval of the most recent prior ECG tracing for purposes of serial comparison. These modifications are currently in progress and are expected to be implemented by September 1, 1981. The availability of automatic storage and retrieval is expected to result in an increase in the number of ECGs that receive a serial comparison since, with manual filing, ECGs are apt to be misfiled or lost.

At several sites, ECG capture by CAPOC was limited because ECG carts were not available for use in all locations where large volumes of ECGs are taken, available equipment was outdated, or some equipment was not functioning reliably. At the time of system installation, some sites were experiencing problems with the interface of existing carts with the automated system due to both technical problems with the interface and communications problems.

By July 1981, problems with equipment interface, telephone access, and telephone transmission had been resolved. Approximately four additional carts are currently on order. Since cart acquisition is the responsibility of the local commands, subject to the availability of procurement funds, acquisition of all carts required to maximize ECG capture by CAPOC will probably not be achieved until September, 1981.

The issue of cart maintenance has also been addressed. In a recent visit, TRIMIS personnel noted a definite improvement in the areas of cart maintenance, training, and availability. The knowledge of site staff of equipment maintenance is considered to be very good. In addition, TPO has recently established a formal dialogue with senior Marquette and Hewlett-Packard personnel and received assurances from both firms of an on-going commitment to provide fast and effective service, where required. A procedure is being established that will appraise TPO of cart maintenance problems so that appropriate action may be taken as quickly as possible.

The Regional CAPOC System Manager, located at San Diego NRMC, has instituted an aggressive training and information-sharing program on a region-wide basis. The program is extremely effective and is meeting with wide acceptance by all users. The Regional Manager has initiated the publication of a monthly "CAPOC Newsletter," which provides a forum for the interchange of ideas and problem resolution, as well as a vehicle for informing (and reminding) users about matters such as system capabilities and projected changes. The Regional Manager has also instituted a training program so personnel from remote sites may travel to San Diego NRMC for refresher and/or familiarization training. When necessary, the Regional Manager can also provide training at the user site. To date, the Manager has made five training visits and this appears to be an effective tool for maintaining a desirable level of user understanding. With facilities available at San Diego NRMC, a video cassette has been produced describing system procedures and capabilities. This film, and additional cassettes concerning ECG cart input and CAPOC editing, will be used as an aide for training of newly assigned personnel and in conducting refresher courses for current personnel.

Operational procedures have been modified at some of the sites so that the unconfirmed CAPOC interpretations of normal ECGs are returned immediately to the physician who ordered the ECG. Other operational changes required to enhance CAPOC benefits are being undertaken.

The actions underway to maximize the benefits of CAPOC in the 18 MTFs in the Southern California area have been extremely successful to date. Resolution of equipment interface, cart availability, and training problems has enabled six sites to begin transmitting ECGs to the system. This will greatly enhance ECG capture by CAPOC in the region. The active involvement of the CAPOC site staff, the Regional Manager, TRIMIS representatives from each service, and the TPO will result in the further changes that are necessary to realize maximum benefits from the system.

CHAPTER 1. INTRODUCTION

A. OVERVIEW

The Tri-Service Medical Information Systems (TRIMIS) Program Office (TPO) has procured a computerized electrocardiography (ECG) system as part of a program known as CAPOC (Computer-Assisted Practice of Cardiology). The overall objective of the CAPOC project is "to improve cardiac diagnosis and treatment in the military health care system by extending high quality ECG analysis service to a larger number of MTFs, many of which do not have cardiology staffs." Specific objectives for the program outlined by the TRIMIS Medical Review Group include:[3]

- "To make enhanced ECG interpretation available to cardiologist and non-cardiologist requesters with increased efficiency and accuracy in the detection and treatment of cardiac disease;
- To have the capability for handling increased demand for ECG interpretation without a significant increase in staff;
- To reduce the clerical work required of qualified ECG technicians in the cardiology service;
- To gather as a result of normal operations, workload and managerial data and to present these as required in order to assist in resource decisionmaking in the MTF;
- To provide accountability for ECG requests and to monitor the generation of interpretation results, to include providing notices of abnormal ECG findings or improper quality control as soon as they are detected; and
- To reduce the number of false negatives (reading an abnormal ECG as normal) interpreted by non-cardiologist physicians."[4]

[3] Initial Project Objectives and Evaluation Criteria, TRIMIS Medical Review Group, September 1, 1977, pages 25-27.

[4] Ibid

The equipment for the CAPOC system was installed by the vendor, Marquette Electronics, in the 18 Medical Treatment Facilities (MTFs) in the Southern California area beginning in October 1979. If the initial CAPOC installations are successful, TRIMIS plans eventually to install 14 more regional computer systems serving MTFs throughout the United States.

B. EVALUATION OBJECTIVES AND METHODOLOGY

Arthur D. Little, Inc., has evaluated the installation of CAPOC in the Southern California area in order:

- to provide TPO with information needed for the proliferation decision;
- to determine whether the system met the objective of extending high quality ECG analysis services to MTFs without cardiology staffs;
- to determine if automated services are cost-effective; and
- to identify changes that should be made to increase the effectiveness of the system or to lower its cost.

This assessment has been accomplished by a comparison of the costs, benefits and acceptance of ECG services before and after the installation of CAPOC in the 18 MTFs involved in the initial system installation.

TRIMIS representatives and evaluation project staff recognized that in addition to improving ECG services, CAPOC would increase the total cost of ECG services. Many of the important anticipated benefits would likely be improvements in the quality of ECG services provided.

In order to relate quantitatively changes in ECG services with changes in costs, an approach was developed that would permit a meaningful comparison of cost-effectiveness of services before and after CAPOC.

The approach developed involved measuring the number of ECGs at each site that met pre-established service criteria in order to quantify the level (effectiveness) of service being delivered. A panel of military physicians helped to develop the criteria for effective ECG services to be used in the evaluation. These criteria established effective service levels for type of staff interpreting ECGs, turnaround time, and use of serial comparison of prior ECGs with current ones. The evaluation effort has been focused upon the collection of data that would allow a determination of the cost per ECG meeting effective service criteria before and after CAPOC implementation.

In addition to the quantitative assessment of the relative costs and performance of manual and CAPOC ECG services, system impacts that are not readily quantified were evaluated by use of interviews and surveys. These factors included staff acceptance of CAPOC, staff perceptions of strengths and weaknesses of manual vs. automated services, the relative importance of ECG service attributes, and patient referral and recall patterns.

CAPOC implementation was planned in a total of 18 MTFs. In order to conduct the evaluation at a reasonable level of effort, five of the MTFs were selected as primary evaluation sites and studied in great detail:

(1) San Diego Naval Regional Medical Center (San Diego NRMC),

(2) Camp Pendleton Naval Regional Medical Center (Camp Pendleton),

(3) USAF Hospital, Nellis Air Force Base (Nellis),

(4) Twentynine Palms Marine Corps Base Branch Hospital (Twenty-nine Palms), and

(5) Miramar Naval Air Station Branch Clinic (Miramar).

These sites represent the range of staffing patterns, patient populations, and ECG services in the region.

So that conclusions could be reached about the system's costs and benefits in the entire region, basic information on ECG services was also collected from each of the remaining 13 medical treatment facilities in the region that were included in the CAPOC system installation. These secondary evaluation sites include:

(1) USAF Hospital, Vandenberg Air Force Base (Vandenberg),
(2) USAF Hospital, Edwards Air Force Base (Edwards),
(3) USAF Hospital, George Air Force Base (George),
(4) USAF Medical Facility, Norton Air Force Base (Norton)
(5) USAF Regional Hospital, March Air Force Base (March),
(6) Long Beach Naval Regional Medical Center (Long Beach),
(7) Naval Station San Diego Branch Clinic (Naval Station),
(8) Naval Air Station North Island Branch Clinic (North Island),
(9) Naval Training Center Branch Clinic (NTC),
(10) Naval Amphibious Base Coronado Branch Clinic (Coronado),
(11) Marine Corps Recruiting Depot Branch Clinic (MCRD),
(12) Port Hueneme Naval Regional Medical Clinic (Port Hueneme), and
(13) Barstow Branch Clinic (Barstow).

Information was obtained at these sites from available records and staff interviews rather than by extensive collection of original data. ECG service characteristics at these sites were matched with those at the five primary sites so that changes due to CAPOC could be estimated based upon similarities in ECG service characteristics.

Finally changes in costs and effectiveness were summed for all 18 MTFs in order to perform a regional analysis of the costs and effectiveness of ECG services before and after the installation of CAPOC.

C. DESCRIPTION OF ECG TECHNOLOGIES

For those readers unfamiliar with computerized ECG technologies, the following brief description is included to provide the background necessary for understanding the CAPOC evaluation.

An ECG is a recording of the electrical activity generated during the heart's contraction. The ECG is obtained by attaching electrodes to the patient's arm, legs, and six positions across the chest. Since the

body conducts electricity, these body surface electrodes record electrical potentials originating within the heart that are transmitted to the surface. An ECG machine records these potentials by selecting different combinations of electrodes, known as "leads." The standard ECG includes 12 leads. These leads can be recorded, one at a time, on a single-channel machine, which produces a long, narrow strip of paper, or they can be recorded three at a time using a three-channel machine, which produces a convenient record for filing (8 1/2 inches by 11 inches in size).

In an ECG department using a manual system, the physician examines the hard-copy record generated by the ECG machine and interprets the wave-forms by comparing measurements of amplitudes and intervals against normal values and/or by recognizing patterns known to be associated with various cardiac conditions. The reader is concerned with identifying patterns associated with cardiac abnormalities (heart attacks, heart enlargement) and disturbances in heart rhythm, known as arrhythmias.

The physician's interpretation is then either written or dictated for transcription. The interpretation is matched with the ECG tracing and filed in the patient's medical record. Often a duplicate tracing and interpretation are kept in an ECG department file. Frequently, the physician compares prior tracings with current ECGs when making an interpretation so that recent abnormalities can be identified. This is referred to as a serial comparison.

Computerized ECG technology, and the CAPOC system in particular, differs in a number of ways from the manual system. It uses a three-channel ECG machine that is equipped to transmit the ECG over telephone lines to a computer. The computer processes these signals, makes measurements on the waveform, compares the measurements with criteria for different conditions, and generates an interpretation. The interpretation (known as the unconfirmed interpretation) is then transmitted back within minutes to the user site, or to any other designated facility. The ECG, along with relevant patient information, is stored in the computer (or on a peripheral storage disk) and can be retrieved at a later time

for comparison with more recent ECG tracings. The unconfirmed interpretation and a hard-copy record of the ECG tracing are usually overread by a physician, who either confirms or edits the computer interpretation. These editing changes can be entered into the computer if user sites are equipped with a data entry terminal.

Use of electrocardiograms in the military is in most ways quite similar to the use of ECG's in civilian medical practice. There are a few differences related to the needs of the military population and the resources available to deliver care. Since ECGs are a non-invasive and relatively inexpensive means of evaluating cardiac status, they are part of the basic cardiac examination for many different types of patients. Electrocardiograms are used to evaluate emergency patients with suspected myocardial infarctions (heart attacks); they are also used to identify cardiac problems such as prior myocardial infarctions or abnormal heart rhythms. The ECG is also used in evaluating apparently healthy individuals to rule out the possibility of any unsuspected problems. For instance pre-operative ECGs are taken to determine whether there are unsuspected cardiac problems that should be known during surgery. ECGs are also routinely taken as part of a routine physical examinations, especially in older male patients. In the military, routine ECGs are also included as part of some physical examinations required for the active-duty population.

Because of the many different types of patients who require ECGs, and because electrocardiograms are taken in emergency situations, it is important to have access to electrocardiography services in all military treatment facilities. The military does not have enough cardiologists (physicians who are expert in reading electrocardiograms) to staff every military treatment facility. Many military facilities are also in remote areas where there are no civilian cardiologists available for back-up. The CAPOC system, which produces a communication network giving small facilities access to consultation from cardiologists in large facilities, is seen as a way to provide high-quality ECG services even for emergency patients in facilities without cardiologists on their staff.

As will be explained later in this report text, the automated ECG services also provide additional benefit in helping to manage the large ECG departments, improve storage and access, save technician time, and improve the quality of the electrocardiogram tracing. However, the primary objective of the CAPOC system is to provide service to small, remote facilities who use electrocardiograms in patient care, but do not have ready access to a cardiologist for interpreting the tracings.

D. OVERVIEW OF EVALUATION ACTIVITIES

The CAPOC evaluation was begun by Arthur D. Little, Inc. in June 1978. CAPOC goals and objectives were reviewed and initial site visits were conducted to the five primary evaluation sites. These visits showed where data could be obtained and provided the necessary background for understanding where impacts due to CAPOC would be likely to occur. An initial evaluation plan was prepared in October 1978.[5] From this plan evolved the final approach for determining the cost-effectiveness of CAPOC in contrast to the manual system, which it has replaced.

The evaluation of ECG services involves several elements: measuring the utilization of services, characterizing the level of services provided, documenting costs of services, and surveying staff about satisfaction with services and areas that could be improved.

Both quantitative and qualitative data were needed in order to conduct a complete evaluation. For each of the five primary evaluation sites, a specific plan for collecting quantitative data was developed. One set of questionnaires was prepared for obtaining qualitative data from all five sites. The methods for quantitative and qualitative data collection were pre-tested and revised. For the 13 secondary evaluation sites, one interview guide was prepared and used for collecting consistent information from all sites.

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[5]"Research Plan for Measuring the Impact of CAPOC in the San Diego Region." Prepared for the TRIMIS Program Office by Arthur D. Little, Inc., October 1978. Prepared under a subcontract with the Johns Hopkins University Applied Physics Laboratory, Contract No. APL600869.

Between August and October 1979, "X" Period data were collected at the five primary sites. In April and May 1980, additional data were collected at these five sites, and interviews were conducted at the other 13 sites.

Installation of the CAPOC system began in October 1979. In September and October 1980, "Y" Period data were collected, reflecting the status of CAPOC implementation 1 year after system installation was begun. Extensive data and information were collected as available at the five primary evaluation sites, and each of the 13 secondary evaluation sites was visited in order to assess the status of system implementation and to characterize the CAPOC ECG process. These data were analyzed.

This report presents the data analysis and findings of the evaluation:

(1) by comparing the costs and effectiveness of the manual and CAPOC ECG processes in the Southern California area, and

(2) by assessing other qualitative impacts of CAPOC as perceived by system users.

Because of problems with equipment interfaces, the automated storage and retrieval function, and operational changes in the ECG process needed at some sites, CAPOC was not fully implemented in the Fall of 1980 when evaluation data were collected. Where data were not available, the impacts of CAPOC at full implementation were projected on the basis of knowledge of the manual services, observations of the system's performance in other sites, and plans underway to achieve full implementation at all sites.

E. ORGANIZATION OF THE REPORT

The remainder of this evaluation report is comprised of five chapters:

- Chapter 2 discusses the methods of data collection and analysis,
- Chapter 3 presents data and information collected related to ECG volumes and service effectiveness of the five primary evaluation sites,
- Chapter 4 summarizes information regarding CAPOC implementation at the 13 secondary evaluation sites, and
- Chapter 5 presents results regarding service effectiveness, costs, and cost effectiveness.

CHAPTER 2. METHODOLOGY

A. OVERALL APPROACH

The overall approach taken in the CAPOC evaluation was a before and after study to document costs, benefits, and staff acceptance of the system. The major features of the methodology employed to compare ECG services before (known as the "X Period") and after (known as the "Y Period") CAPOC implementation were dictated by the objectives for the evaluation, the anticipated benefits of automating ECG services, and the need to conduct the evaluation at a reasonable cost.

Since it was recognized that CAPOC was likely to increase the costs of providing ECG services in MTFs in the Southern California area, while at the same time improving the quality of services provided, the evaluation had to value costs and benefits of the system. Though changes in ECG services--such as improved service response times, increased accuracy of ECG reading, and increased availability of prior ECGs for serial comparison--could be measured, they were difficult to translate into dollar value for a direct comparison with system costs. For example, a reduction in turnaround time for receipt of an ECG interpretation for a pre-operative patient from 20 hours to 4 hours might be of real benefit to patient care, but the value in dollars would be difficult to estimate. Similarly, an increase in availability of prior ECGs would facilitate use of serial comparisons, but the value of serial comparisons to clinical decisionmaking could not be expressed easily as a dollar value. Therefore, an evaluation measure was needed that could both capture significant changes in the important service benefits and relate them to changes in costs in a combined measure of the usefulness or value of the system.

Discussions with users, combined with experience in civilian health care facilities, indicated that CAPOC would improve service in three major areas:

(1) The time required to receive an ECG interpretation would decrease in remote sites (many of which previously sent ECGs through the mail for reading);

(2) Interpretations of ECG tracings would be more accurate and consistent; and

(3) Access to prior ECG tracings would improve, and the frequency with which current ECGs were compared with prior ECGs in order to identify changes would increase.

Based upon these service attributes, a panel of users identified two levels of effective ECG services: what is typically required for the ECG to be useful in clinical management of patients (acceptable ECG services) and what permits the maximum benefit from ECG information in clinical decisionmaking (preferred service). Together these two levels of effective service provided the evaluation measure used to quantify changes in service quality.

When the measured changes in service quality were combined with information regarding the costs of providing ECG services with and without CAPOC, the cost-effectiveness of the two service modes could be compared. If the cost per effective ECG was lower with CAPOC, the system would be considered to have met its objectives.

The initial CAPOC installation involved a total of 18 MTFs, many of which provided ECG services in several different locations. Documenting multiple system impacts in each of these ECG service settings would have required a massive evaluation effort. Therefore, a decision was made to focus intensive evaluation efforts on a sample of carefully selected sites and to project the likely impacts of CAPOC for the remainder of the sites.

Primary evaluation sites were chosen to be representative of the type of staff, patient population, and ECG services in the region. The five selected included the largest referral hospital in the region; one smaller referral hospital; one small branch clinic; one small, remote branch hospital; and one small hospital that was not affiliated with a large center. The five sites included Navy, Marine, and Air Force facilities (no Army MTFs are located in the Southern California area).

Information on ECG services in the primary evaluation sites was obtained by on-site data collection, review of hospital statistics, interviews with staff, and administration of a staff survey. The additional

thirteen sites in the region were visited briefly, and a description of the ECG process was obtained. On the basis of this information and data from the five primary sites, levels and costs of ECG services as provided before and after CAPOC were estimated for the entire region.

In addition to measured changes in service effectiveness (by use of the set of service criteria), CAPOC was expected to have other important benefits that are more difficult to quantify. Furthermore, one objective of the evaluation was to provide insight into staff acceptance of CAPOC and to identify changes in the CAPOC system and its use that would increase benefits and/or reduce costs. Therefore, the quantitative evaluation was supplemented by a qualitative assessment of a number of other aspects of ECG services. This was accomplished by a survey of users and providers of ECG services at the primary evaluation sites and by interviews with staff at the secondary evaluation sites.

In summary, ECG services before and after CAPOC installation were compared by a quantitative and qualitative assessment in a sample of sites, with the results projected to the entire region. The quantitative evaluation was focused on the relative costs and performance of manual and CAPOC services, as measured against criteria for effective ECG services.

The remainder of this chapter describes the development of the evaluation criteria and the techniques for data collection and analysis.

B. DEVELOPMENT OF CRITERIA FOR EFFECTIVE ECG SERVICES

1. Identification of Important Service Parameters

Establishing criteria for effective ECG services required identifying parameters that are important in determining the clinical usefulness of the ECG. These parameters were identified by reviewing information collected during the original site visits and noting where changes were anticipated and by interviewing staff at the sites concerning their expectations of changes that would result in benefits to patient care. Five factors were identified by this process:

- Turnaround time (elapsed time between taking of the ECG tracing and the return of the interpretation),
- Use of serial comparison (comparing the current ECG tracing with a prior one and noting differences),

- Patient population receiving ECGs,
- Type of staff interpreting the ECGs, and
- Accuracy, consistency, and completeness of the interpretation.

The first four factors were considered further in this study. A separate accuracy evaluation is also planned.

2. Need for Service Levels

Before improvements in these parameters could be quantified, however, it was necessary to distinguish those changes that would affect patient care from less significant changes. The need for this differentiation is illustrated in the following example regarding changes in service response time.

A decrease in turnaround time from 14 days to 7 days or from 8 hours to 4 hours might not result in a 100% increase in the usefulness of the ECG. In order to value this potential benefit, it is necessary to examine how these reduced turnaround times might actually affect patient care.

In the case of an outpatient ECG, three different uses of the ECG have been defined. First, if the ECG interpretation were returned very quickly (within 30 minutes), the patient could wait at the MTF while the results were reviewed. In this case, the information derived from the ECG could be reflected immediately in the decisionmaking of the attending physician. If the interpretation were received within 3 days, the physician would most likely still have easy access to the patient's chart and could integrate the ECG information with other laboratory information, and make a decision about whether the patient should be recalled for follow-up evaluation or treatment initiation. If, however, the ECG were returned after 3 days, the physician might have to recall the patient's chart from the record room in order to consider the ECG information, in conjunction with patient history and other test results, or the patient information might not be reviewed until the next patient visit.

On the basis of these described differences in patient care, three levels of service could be defined for the turnaround time for receipt

of the interpretation: within 30 minutes, within 3 days, and over 3 days. For this theoretical example, a change in turnaround time from 1 day to 30 minutes would represent a significant change since it would affect the way the ECG was used in patient care. However, a change from 8 hours to 4 hours would not be considered significant since the way the ECG could be used in patient care would not be affected.

As this example illustrates, the information derived from an ECG can have various degrees of usefulness in patient care depending upon the turnaround time, and ranges in turnaround time can be defined to correspond to theoretical levels of service. In a similar manner, criteria can be established for other parameters that affect how useful the ECG is in patient care.

3. Development of Criteria

In order to establish service criteria to be used in evaluation of ECG services, it was important to have a thorough knowledge of the patient population being served, and the different uses for electrocardiograms within the military health care system. With the assistance of the CAPOC representatives, a letter was sent to military medical personnel in the Army, Navy and Air Force, seeking their views on standards for ECG services relating to the four service parameters identified:

- Turnaround Time
- Use of Serial Comparison
- Patient Population Receiving ECGs
- Type of Reader

Respondents were asked to provide values that represented acceptable services and preferred services for different types of patients and ECGs [e.g., acceptable and preferred turnaround times were requested for routine, STAT (emergency) and pre-operative inpatient ECGs, Emergency Room ECGs, and diagnostic and other outpatient ECGs]. Respondents were also asked for their views of other important factors that should be considered when defining preferred and acceptable ECG services. The request also stated that the purpose of the criteria was to specify what was desirable--not what was feasible, or what existed at the time. A total of 55 responses were received and used in establishing criteria.

A consensus development meeting was then held to review the responses and establish the criteria that would be used in the evaluation. The meeting was attended by at least one cardiologist, one internist or general practitioner, and one technician from each of the three military services. The consensus group concluded that establishing criteria for patients who should receive ECGs was not possible and, further, that deciding on the basis of statistical information whether an increase in ECG usage for a given patient population was appropriate or beneficial would be impossible. The group did achieve a consensus on levels for preferred and acceptable services for the remaining three parameters: turnaround time, type of reader, and use of serial comparisons. These criteria are shown in Table 2-1.

For each type of ECG, the data regarding X and Y Period ECG services at the evaluation sites were compared with each criterion in order to determine whether preferred of acceptable levels of ECG services were being delivered. In order for an ECG to be considered preferred, it had to meet all ECG service criteria for preferred service. In order for an ECG to be considered acceptable, it had to either meet all acceptable criteria or meet preferred or acceptable levels for all criteria; for example, if an ECG met preferred criteria for reader and serial comparison and met acceptable criteria for turnaround time, this ECG was considered acceptable. Together, ECGs meeting preferred criteria and acceptable criteria are referred to as effective ECGs.

C. DATA COLLECTION

1. Quantitative Data

The quantitative portion of the CAPOC evaluation required information regarding ECG volumes and types, service effectiveness as measured against the evaluation criteria, and the costs of providing ECG services. These data were collected at the five primary evaluation sites by observation, on-site data collection, and review of hospital and ECG department records. Table 2-2 summarizes the data collection techniques used for each of the data elements. In most instances, interviews and and direct on-site observations were used to confirm the results of the data collection.

TABLE 2-1

CRITERIA FOR EVALUATING THE EFFECTIVENESS OF ECG SERVICES

Service Parameter	Acceptable Service	Preferred Service
	What do you consider to be an acceptable turnaround time for the ECG interpretation in order to be useful in clinical management of the patient?	What do you consider to be the optimal turnaround time to get maximum benefit from ECG information in clinical decision-making?
Turnaround Time:		
Inpatient ECGs		
Routine	2 days	1 day
STAT	30 minutes	15 minutes
Pre-operative[1]	24 hours	12 hours
Emergency Room	30 minutes	15 minutes
Outpatient ECGs		
Diagnostic (for that visit)	30 minutes	30 minutes
(for future visit)	3 days	N/A
Annual Physical and Other Screening	7 days	2 days
Training of ECG Reader:	What staff do you feel can provide "acceptable ECG reading" in the following ECG reading tasks?	What staff do you feel provide "optimal ECG reading" for the following ECG reading tasks?
In a Manual Setting		
Classify Normal Tracings, Refer Only Abnormal Tracings for Reading	Internist or Cardiologist	Cardiologist
Make Initial Reading of Normal and Abnormal, Refer for Overreading	Internist or Cardiologist	Cardiologist
Make Final Interpretation of Normal and Abnormal ECGs	Internist or Cardiologist	Cardiologist
With Computer-Assisted Reading		
Certify Normal Interpretations Refer Abnormal Interpretations for Overreading	Corpsman/ECG Technician, Nurse, or Any Physician	Corpsman/ECG Technician, Nurse, or Any Physician
Overread Computer Interpretations	Internist or Cardiologist	Cardiologist
Availability of a Serial Comparison:	At a minimum which ECGs do you feel should receive a serial comparison?	In an optimal system, which ECGs would receive a serial comparison?
	All Abnormal ECGs	All Abnormal ECGs

[1] For pre-operative ECGs turnaround time was defined from the time the ECG was taken to the time that the official interpretation was available in the patient's chart. For other ECGs turnaround time was defined from the time the ECG was taken until the interpretation was returned and made available to the care provider.

TABLE 2-2

DATA COLLECTION METHODS

Data Element	X Period		Y Period	
	Primary Sites	Secondary Sites	Primary Sites	Secondary Sites
ECG Volume	ECG logs and observation	Interviews and ECG logs when available, morbidity reports	Computer logs for CAPOC volume, manual records for ECGs not captured by CAPOC	Computer logs and interviews, morbidity reports
Types of ECGs Processed	Sample of ECGs during observation period, ECG log	Interviews and ECG logs	Sample of ECGs during observation period, ECG logs, and in a few instances, computer logs	Interviews and ECG logs
Service Effectiveness Criteria:				
Turnaround Time	Tracking of a sample of ECGs by use of time stamps and/or self-reporting; observation of ECG process	Interviews (tracking in two sites)	Tracking of a sample of ECGs by use of time stamps and/or self-reporting; observation of ECG process	Interviews
ECG Reader	Sample of ECGS during observation period, physician staffing patterns	Interviews, physician staffing patterns	Sample of ECGs during observation period, physician staffing patterns	Interviews, physician staffing patterns
Serial Comparison	Sample of ECGs during observation period	Interviews	Sample of all ECGs during observation period	Interviews
Costs:				
Labor	Measurement of physician reading time (confirmed by questionnaire) and technician time devoted to ECG activities (one site), observation and interviews	Interviews	Measurement of physician reading time and technician time (one site), observation and interviews	Interviews
Supplies	Ordering records supplemented by interviews and observation of ECG process	-	Ordering records, supplemented by interviews and observation of ECG process	-
Equipment	Inventory of equipment in use, interviews (age of equipment, maintenance)	Interviews	CAPOC contract documents, inventory of equipment in use	Interviews

A series of data collection forms was developed to facilitate recording of data. Procedures and data collection instruments were pre-tested at Camp Pendleton NRMC in February and March 1979. After the pre-test, the data collection protocol was modified to accommodate the specific mode of operation and recordkeeping practices at each primary evaluation site.

2. Qualitative Information

Collection of qualitative information was accomplished by a survey of staff and staff interviews at primary evaluation sites and by interviews with staff at the secondary evaluation sites.

Two versions of a staff questionnaire were developed for use before and after the installation of CAPOC. The factors to be evaluated by the qualitative assessment pertained to staff acceptance of CAPOC, changes in patient referral patterns, staff satisfaction with ECG services, perceived accuracy of interpretations, relative importance of attributes of ECG service, and time devoted to performing ECG reading functions.

All questionnaires were designed so that they could be filled in without assistance from other staff or the research team. Questionnaires were also designed to be anonymous. The respondent's date of birth was used as an identifier so that responses to the two surveys could be compared.

Questionnaires and methods for administering them were pre-tested during February 1979 at Long Beach Naval Regional Medical Center. This site was selected because it was one of the largest hospitals among the secondary evaluation sites. In all, 16 staff members at Long Beach completed the staff questionnaire and were interviewed. Professional staff appeared to be able to complete the questionnaires easily. They made some suggestions regarding terminology that were incorporated in a revised questionnaire (see Appendix A for X and Y Period questionnaires).

Obtaining completed questionnaires from busy staff members was the major problem identified. This pointed out the necessity for having a cover letter requesting cooperation signed by the Chief Medical Officer to accompany the questionnaire. Therefore, plans were made to contact

the appropriate staff at each study site well in advance of the visit to arrange for the production of such a letter, to obtain assistance in identifying the sample population, and to establish procedures for questionnaire distribution and return.

Information collected at the secondary sites was largely qualitative in nature, obtained through interviews with staff involved with ECG services. So that consistent information was obtained at each site, a detailed interview guide was prepared and used (see Appendix B for X and Y Period interview guides). At some of the secondary sites actual data concerning ECG volumes were obtained and in a few cases a limited amount of original data collection was undertaken.

D. DATA ANALYSIS

1. Quantitative Data

a. ECG Volumes

Information regarding ECG volumes was necessary for projecting the measured service effectiveness to all ECG services and for computing the costs per ECG processed in each site and in the region. Because of different recordkeeping practices in the different sites and the importance of the number of ECGs in the calculation of cost-effectiveness and the conclusions, X and Y Period volume data for each site were scrutinized for reasonableness and major discrepancies or changes in volumes between the X and Y Periods were explored. In one case (March AFB) the baseline data were adjusted to reflect an annual volume of 6,000 rather than 10,608 ECGs where it was discovered that data in the baseline reflected duplicate tracings taken on the same patient.

In some cases, portions of the ECG volume for a given site had to be estimated from a combination of data sources. This was particularly true for X Period data, which had to be reconstructed from only available records. The actual volumes used in the analysis are based upon best judgments of reasonable values.

The data revealed an 11% drop in ECG volume in the region from the X Period (1979) to the Y Period (1980). Though the cause of this change has not been identified, there are several plausible explanations:

(1) The baseline data are in error. Since baseline data were collected from manual records, and in many cases, Y Period data were automatically collected by the system, the manual records may reflect estimates instead of accurate counts of ECGs taken.

(2) The CAPOC system lead to fewer repeat duplicate tracings because of lost or delayed interpretations or poor quality tracings. Most physicians surveyed felt that repeat duplicate tracings had declined as a result of CAPOC; however, there are no data to confirm the magnitude of this impact.

(3) The volume actually did decrease due to changes in patient population or medical practice. (It is interesting to note that data from surveys of civilian ambulatory medical care show a decline of ECG volume of 24% between 1978 and 1979.)

The initial analysis was performed with the volume data as collected. If the system resulted in a reduction in duplicate tracings and/or the volume did decline, the CAPOC system would be more cost-effective than the analysis indicates.

The impact of the CAPOC system on effectiveness of services also depends upon the mix of normal and abnormal ECGs (since different types of physicians are considered effective and preferred readers for normal and abnormal tracings). The effective turnaround time is dependent on the type of patient involved, for example, pre-operative ECGs are required sooner than routine outpatient ECGs. Therefore, the mix of patients receiving ECG services had to be determined accurately in the evaluation.

At the secondary evaluation sites, the type of ECGs taken in the baseline period were estimated. After CAPOC implementation, often better records (or different estimates) of the types of ECGs were obtained. Where the differences were large, the sensitivity of conclusions to different assumptions was examined.

b. Service Performance Measured Against Evaluation Criteria

The quantitative evaluation was focused on determining the annual number of ECGs at each site meeting criteria for acceptable and preferred

TABLE 2-3 DATA CONCERNING INDIVIDUAL SERVICE CRITERIA IN THE X PERIOD AT SAN DIEGO NAVAL REGIONAL MEDICAL CENTER

Type of ECG	Routine Outpatient ECGs			Annual Physical ECGs			Routine Inpatient ECGs			Pre-Operative ECGs			Stat/Emergency Room ECGs		
		Percent of Routine Outpatient ECGs Meeting Criteria			Percent of Annual Physical ECGs Meeting Criteria			Percent of Routine Inpatient ECGs Meeting Criteria			Percent of Pre-Operative ECGs Meeting Criteria			Percent of Stat/Emergency Room ECGs Meeting Criteria	
	Data (Source*)	Preferred	Acceptable**	Data (Source*)	Preferred	Acceptable**	Data (Source*)	Preferred	Acceptable**	Data (Source*)	Preferred	Acceptable**	Data (Source*)	Preferred	Acceptable**
Percent of Total ECG Volume	33% (A)			3% (A)			42% (A)			15% (A)			7% (A)		
Normal ECGs															
Percent of Type That Are Normal	35% (A)			56% (A)			37% (A)			59% (A)			55% (A)		
Turnaround Time	Within 3 Days (A)		100%	Within 2 Days (A)	100%		58% Within 1 Day (A) 34% in 1-2 Days (A)	58%	34%	30 Hours (A)			Less Than 15 Minutes (A)	100%	
Reader	93% Cardiologist (A) 7% Resident (A)	93%	7%	89% Cardiologist (A) 11% Resident (A)	89%	11%	87% Cardiologist (A) 13% Resident (A)	87%	13%	Cardiologist (A)	100%		Internist (A)		100%
Abnormal ECGs															
Percent of Type That Are Abnormal	65% (A)			44% (A)			63% (A)			41% (A)			45% (A)		
Turnaround Time	Within 3 Days (A)		100%	Within 2 Days (A)	100%		58% Within 1 Day (A) 34% in 1-2 Days (A)	58%	34%	30 Hours (A)			Less Than 15 Minutes (A)	100%	
Reader	87% Cardiologist (A) 13% Resident (A)	87%	13%	Cardiologist (A)	100%		85% Cardiologist (A) 15% Resident (A)	85%	15%	Cardiologist (A)	100%		Internist (A		100%
Percent of Abnormal ECGs Receiving Serial Comparison	63% (A)	63%		72% (A)	72%		46% (A)	46%		31% (A)	31%		14% (A)	14%	

* Sources of Data
A – Actual data reported or measured for site
I – Data obtained during interview with staff
E – Estimated number based upon experience at another site

** In this Table, in contrast to the text, columns that are labelled acceptable exclude the percent that is also preferred. This was done in order to simplify the calculation of ECGs meeting all criteria and to simplify estimates of the impact of changes in service on each of the data elements. Since ECGs meeting preferred criteria are a subset of those meeting acceptable criteria, the total number of ECGs meeting acceptable criteria as reported in the text can be computed from the values shown in this Table by summing the percentages in the preferred and acceptable columns

TABLE 2-4

CALCULATION OF NORMAL ECGs MEETING ECG SERVICE CRITERIA--
X PERIOD DATA FOR SAN DIEGO NAVAL REGIONAL MEDICAL CENTER

TYPE OF ECG	Percent Normal By Type	Percentage by Type: Turnaround Time Preferred	Turnaround Time Effective	Reader Preferred	Reader Effective	Meeting Criteria for Percentage Meeting All Criteria: Preferred	All Criteria Effective	Percent of Total Volume: Total	Preferred	Effective
Routine Outpatient	35	0	100	93	100	0	100	33	0	11.6
Annual Physical	56	100	100	89	100	89	100	3	1.5	1.7
Routine Inpatient	37	58	92	87	100	50.5	92	42	7.8	14.3
Pre-Operative	59	0	0	100	100	0	0	15	0	0
STAT/Emergency Room	55	100	100	0	100	0	100	7	0	3.8

Note: Effective ECGs are all ECGs meeting at least the criteria for acceptable services for each criterion (turnaround time, ECG reader, serial comparison). A subset of these ECGs is those that also meet the more stringent preferred service criteria in each case. So that changes in two levels of service could be differentiated from each other, the subsequent analysis considers two categories of effective ECGs: those that met criteria for acceptable services but not those for preferred services (called "acceptable ECGs") and those that met the preferred service criteria.

TABLE 2-5

CALCULATION OF ABNORMAL ECGs MEETING ECG SERVICE CRITERIA--
X PERIOD DATA FOR SAN DIEGO NAVAL REGIONAL MEDICAL CENTER

TYPE OF ECG	Percent Abnormal By Type	Percentage by Type Meeting Criteria for: Turnaround Time Preferred	Turnaround Time Effective	Reader Preferred	Reader Effective	Serial Comparison Preferred	Serial Comparison Effective	Percentage Meeting All Criteria Preferred	All Criteria Effective	Percent of Total Volume Total	Preferred	Effective
Routine Outpatient	65	0	100	87	100	63	63	0	63	33	0	13.5
Annual Physical	44	100	100	100	100	72	72	72	72	3	1.0	1.0
Routine Inpatient	63	58	92	85	100	46	46	22.7	42.3	42	6.0	11.1
Pre-Operative	41	0	0	100	100	31	31	0	0	15	0	0
STAT/Emergency Room	45	100	100	0	100	14	14	0	14	7	0	.4

Note: Effective ECGs are all ECGs meeting at least the criteria for acceptable services for each criterion (turnaround time, ECG reader, serial comparison). A subset of these ECGs is those that also meet the more stringent preferred service criteria in each case. So that changes in two levels of service could be differentiated from each other, the subsequent analysis considers two categories of effective ECGs: those that met criteria for acceptable services but not those for preferred services (called "acceptable ECGs") and those that met the preferred service criteria.

ECG services. The basic approach was to obtain data on a sample of ECGs and project the results to the annual volumes.

An example of how this was accomplished is shown in Tables 2-3, 2-4, and 2-5 for X Period data for San Diego Naval Regional Medical Center. In the first table, the quantitative data on turnaround time, ECG reader, and serial comparison are summarized for normal and abnormal ECGS broken down into five service categories:

routine outpatient
annual physical
routine inpatient
pre-operative
STAT/Emergency Room

Each of these service categories must be considered separately because the criteria for turnaround time are different for each. Likewise, abnormal and normal ECGs must also be considered separately because the criteria for reader and serial comparison differ.

All data shown in Table 2-3 are percentages of a sample of the ECG volume (at San Diego NRMC 902 ECGs and 865 ECGs were sampled in the X and Y Periods respectively). As noted under the column "Data Source" for each service category, data for San Diego NRMC were all actual data reported for or measured at the site; for certain data at other primary sites and for most data at secondary sites, data were obtained in interviews or estimated based upon information from a similar site.

Once the data on services had been complied, they were compared with the evaluation criteria in order to analyze what percentage of ECGs processed at the site meet acceptable and preferred service criteria. The manner in which this was accomplished is shown in Table 2-4 for normal ECGs and Table 2-5 for abnormal ECGs; again the data are for the X Period at San Diego NRMC.

For each type of ECG, the percentages meeting acceptable and preferred criteria for turnaround time, ECG reader, and serial comparison were computed. ECGs had to meet all criteria for preferred services in order to be considered preferred ECGs; they had to be rated as acceptable or preferred for each criterion in order to be considered effective ECGs. Percentages of ECGs meeting the three criteria were applied in a step-

wise fashion in order to compute the percentage of each type and of the total volume that met criteria for acceptable and preferred services.

The following example of this procedure is taken from Tables 2-4 and 2-5 and concerns routine inpatient ECGs. As noted in Table 2-3, 56% of these ECGs were normal. Of all normal, routine inpatient ECGs, 58% were returned within 1 day and a total of 92% (58% + 34%) were returned within 2 days. Hence 58% met the criterion for preferred turnaround time and 92% met the criterion for effective (preferred plus acceptable) turnaround time.

For this site, 87% of the normal, routine inpatient ECGs are read by a cardiologist (a preferred reader according to the evaluation criterion). All (100%) of these ECGs are read by an effective reader.

The percentage meeting all criteria is the product meeting each separate criterion. Thus the percent meeting preferred criteria is

58% (turnaround time) x 87% (reader) = 50.5% (all criteria).

Normal ECGs account for 37% of all routine inpatient ECGs which, in turn, account for 42% of the total volume. Thus, normal, routine inpatient ECGs contribute:

50.5% (all criteria) x 37% (normal) x 42% (routine inpatient) = 7.8% to the total preferred level of service.

The criteria for serial comparison must be included in the calculation of abnormal ECGs meeting all the criteria. As seen in Table 2-3, 46% of the abnormal, routine inpatient ECGs receive a serial comparison. The calculation of percent of these ECGs meeting preferred criteria is:

58% (turnaround time) x 85% (reader) x 46% (serial comparison) = 22.7%.

This number is then carried through in the same manner as the calculation for the normal ECGs.

Preferred ECGs meet all the criteria for preferred level of service. Effective ECGs are the sum of ECGs meeting preferred service criteria and of ECGs meeting acceptable, but not preferred, services. In subsequent discussions and tables, the term effective ECG refers to this sum. Acceptable ECGs can be determined in the calculation by taking the appropriate difference.

This same procedure was followed for each of the 18 evaluation sites for both the X Period and the Y Period (a computer program was eventually developed for performing the calculations). At some sites where CAPOC was not yet capturing the entire ECG volume when Y Period data were collected, two analyses were performed: one calculating the effectiveness of the CAPOC portion of the volume and one calculating the effectiveness of the manual portion of the volume. In addition, system performance when CAPOC is fully implemented was projected and the resulting service effectiveness calculated.

c. Cost Analysis

(i) Introduction

Measurements of costs of ECG services in the X and Y Periods were essential in order to determine the cost-effectiveness of manual vs. CAPOC services. Five separate direct cost elements were identified and used in the analysis:

- labor costs,
- supply costs,
- capital equipment costs,
- maintenance costs, and
- system costs (Y Period only).

Overhead costs were considered initially. However, because information on overhead cost allocations was available for only one site (Camp Pendleton), these costs were not included in the initial cost calculations. The effect of the overhead is considered in the sensitivity analysis.

Because of data limitations, several different methods were utilized to compile the costs. When available, actual data from the site were used in arriving at the costs for the individual elements. If data were unavailable for a site, data from another site that was determined to be similar in such areas as ECG process, size, and volume were scaled and/or adjusted as required in order to obtain an estimate for the site.

The Y Period analysis consisted primarily of a differential cost analysis. Differential costs are those costs that resulted from the installation of CAPOC. In order to perform the differential cost analysis

each element is examined in order to determine additional costs, savings, or trade-offs resulted from use of the system. These are then added to the X Period (manual system) costs to estimate the costs of services with CAPOC.

Specific methods and data used for each data element are summarized in the following section.

(ii) Cost Elements

(a) Labor Costs

Labor costs are comprised of two components:

- the cost for the physician time devoted to reading the ECG, and
- the cost for the ECG technician time spent performing the various functions involved in the overall ECG process.

Thus calculating the labor costs required information about the cost of labor and the time devoted to the ECG process.

Labor costs were based on actual average pay rates for the various personnel concerned. The average base salary was multiplied by 1.38 to reflect the value of medical and retirement benefits. This product was in turn multiplied by 1.209 to reflect leave and holiday pay. Thus, base salaries were adjusted by a factor of 1.668. In order to obtain the composite salary, any allowance for quarters or other special payments are added to the adjusted salary. A cost per hour was obtained by dividing the composite salary by 2080 hours. A summary of labor costs for all categories of personnel is presented in Table 2-6.

Several different methods were employed to determine the time spent by the various staff types involved in the ECG process. Reading times for normal and abnormal ECGs or for all ECG were obtained by direct observation, through questionnaires, and by interviews. Where necessary, data from a similar site were used for a site were no data were available. Data on type of reader--i.e., cardiologist, internist, general practioner, or resident--were obtained from interviews or review of ECG interpretations. These data were combined with the volume of ECGs for each site

TABLE 2-6

SUMMARY OF HOURLY LABOR COSTS*

Staff Type	Typical Pay Grades	Base Salary	Quarters and/or Other Allowances	Composite Salary	Hourly Cost
Cardiologist	5-6	$29,987	$10,933	$60,964	$29.31
Internist	5-6	$29,987	$10,933	$60,964	$29.31
General Practitioner	3-4	$20,806	$ 7,623	$42,336	$20.35
Resident	3	$18,894	$ 7,283	$38,806	$18.66
Technician	E-4	$ 7,408	$ 3,373	$15,733	$ 7.56
	E-3	$ 6,480	$ 2,728	$13,539	$ 6.51

*Salaries are in 1980 dollars.

in order to calculate total reading cost. The general overall calculation of reading cost for a site may be summarized as follows:

$$\sum_{\text{All normal ECGs}} N \times R_{iN} \times T_N \times C_i + \sum_{\text{All abnormal ECGs}} A \times R_{iA} \times T_A \times C_i$$

where:

- N = annual volume of normal ECGs at the site,
- R_{iN} = percent of normal ECGs read by reader type i,
- T_N = time required to read one normal ECG,
- C_i = labor cost for reader type i,
- A = annual volume of abnormal ECGs at the site,
- R_{iA} = percent of abnormal ECGs read by reader type i,
- T_A = time required to read one abnormal ECG, and
- i = reader type: cardiologist, internist, general practitioner, resident.

The differential costs due to the installation of CAPOC were determined in the Y Period by multiplying the difference in reading time per ECG by the appropriate cost per unit time and annual ECG volume. This yielded the differential cost for reading labor.

Two different approaches were used to calculate technician costs for processing ECGs. At sites where one or more technicians were assigned to handle ECGs exclusively, the labor cost was determined by multiplying the number of technicians by the average annual composite salary. In sites where technicians had other duties not directly related to ECGs, an average time per ECG was obtained. These values were either measured or were estimated through interviews. The average time per ECG was multiplied by the annual ECG volume and the unit cost of labor to determine the total annual technician labor cost.

A marginal cost for technician labor was calculated for the Y Period based upon change in time and/or elimination of an activity due to

CAPOC. The time per ECG was multiplied by the annual ECG volume and the cost per unit time to yield the total difference.

(b) Supply Costs

Two methods were used to estimate supply costs in the X Period. Wherever possible, supply costs were based on actual cost per item and actual total number of items ordered in a one-year period.

At some sites, however, the data on supply usage and costs were not available. For these sites a cost per ECG was calculated on the basis of knowledge of the ECG process and data on average unit cost for each item used (obtained from sites where information was available). The cost per ECG was multiplied by the annual volume to yield the annual supply costs for a facility.

In the Y Period analysis, it was necessary to identify both increased costs due to such factors as more expensive paper and cost savings due to elimination or reduction of certain supplies. All cost differences were based upon unit costs per ECG multiplied by the annual ECG volume.

(c) Capital Equipment Costs

Capital equipment costs for the X Period were limited to ECG cart costs. The age of the ECG carts and purchase prices varied widely. The useful lifetime for this type of equipment is generally considered to be 5 years (three-channel transmitting carts) or 7 years (single-channel or three-channel non-transmitting carts). A number of carts in use in the 18 CAPOC sites had exceeded their useful lifetime for depreciation purposes, and therefore, might be considered to have no cost associated with their continued use. Probably, these carts should have been replaced (the unreliability of outdated equipment was a recurring physician comment at many sites).

However, in order to assign a value to all equipment for the purposes of this evaluation, an average annual cost was calculated for each type of cart, i.e., single-channel, three-channel, non-transmitting, and three-channel transmitting, based on actual purchase prices and assumed lifetimes

of 5 years or 7 years. The cost range, average costs, and lifetime and annual cost for each piece of equipment are summarized in Table 2-7. This average annual cost was assigned to all carts irrespective of their age. (Y Period capital costs are discussed under system costs.)

(d) Maintenance Costs

Equipment maintenance costs were of two types: fixed-price contracts and maintenance performed by the site staff. When the equipment was covered by a maintenance contract (six sites), the annual contract price was used. Three sites maintained records on maintenance and repair time for the ECG equipment. From these data, an average annual maintenance time for a single-channel and a three-channel cart was calculated. These times were converted to an annual cost using the pay rate of an E-4 technician. These average costs were then applied to the eight sites where data were not available. The average annual maintenance cost for a single-channel ECG was $38, for a three-channel ECG cart, $71.

(e) System Cost (Y Period Only)

System costs were obtained from the contract negotiated with the vendor. Five cost elements were specifically identified in the contract:

- initial costs--including training and software conversion,
- lease payments,
- equipment purchase price,
- maintenance and software costs, and
- communication costs.

In addition to these costs, other costs were incurred by the sites for the purchase of additional equipment and additional supplies. Site-specific costs were obtained from the sites. These two categories of cost comprise the expenses directly attributable to the CAPOC system.

(iii) Life-Cycle Cost Calculations

In order to calculate an average annual cost, a life-cycle cost calculation was performed. The CAPOC system life was taken to be 8 years. For each year in the system life, the expenses and savings were calculated

TABLE 2-7

EQUIPMENT COSTS

Type of Cart	Average Cost	Lifetime	Average Annual Cost
Single-Channel	$1,308	7 years	$ 187
Three-Channel, Non-Transmitting	$5,762	7 years	$ 823
Three-Channel, Transmitting	$7,788	5 years	$1,558

by one of several methods depending upon the cost elements. Initial and equipment costs (lease then purchase) were specified in the contract with the CAPOC vendor. Maintenance/software and communication costs were specified in the contract and included an escalation factor of 10 percent annually after the second year. Paper costs were escalated at 10 percent annually after the first year. Savings were also escalated. Differences in paper and supply costs were escalated at 10 percent annually after the first year. Labor savings were escalated at varying yearly rates according to a DoD schedule of projected labor cost increases.

For each year of system life the sum of expenses and the sum of savings were then discounted at 10 percent in order to obtain a net present value. The net present value of costs minus the total net present value of the savings gave the total system life-cycle cost. The total system life-cycle cost divided by the system life time yielded the incremental annual cost of the CAPOC system, which was used in the cost-effectiveness analysis.

(d) Cost-Effectiveness Analysis

The cost effectiveness of ECG services was obtained by dividing the total annual cost of service by the number of effective ECGs to yield a cost per effective ECG. Actually, two cost figures were calculated in each period. A cost per effective ECG (the sum of ECGs meeting acceptable and preferred criteria) and a cost per ECG at the preferred level of service. The X Period costs were the summation of each cost time discussed previously. The Y Period costs were the sum of the X Period cost plus the incremental annual cost due to CAPOC.

(e) Sensitivity Analysis

In performing the analysis of service effectiveness, several assumptions were required concerning various aspects of the ECG process. For example, certain portions of the costs, specifically the variable costs, are directly related to the number of ECGs processed. Several different scenarios were evaluated in order to estimate the magnitude of the effect of major assumptions on the conclusions about cost-effectiveness.

2. Qualitative Information

Questionnaire results for the X and Y Periods were analyzed from data tabulations prepared with the aid of a computer program. Information relating to desired turnaround times and time devoted to ECG reading was plotted on a distribution chart. Responses regarding the importance of attributes of ECG service and satisfaction were weighted (e.g., +2 for very good, +1 for good, etc.) and tabulated so that they could be compared more readily.

Many of the survey questions were related to the service effectiveness criteria used in the quantitative portion of the evaluation. The responses tc these questions were analyzed in order to identify areas of agreement or disagreement with the evaluation criteria and the quantitative findings regarding service effectiveness.

The questionnaire also allowed for fill-in responses and free-form comments about any aspect of ECG services. These provided insight into problems or special conditions at each primary site. This information was combined with the results of interviews conducted during site visits to reach conclusions regarding the experience with CAPOC implementation at each site.

CHAPTER 3. SERVICE EFFECTIVENESS--PRIMARY SITES

A. SAN DIEGO NAVAL REGIONAL MEDICAL CENTER

1. Introduction

San Diego Naval Regional Medical Center is the largest military treatment facility with the largest cardiology staff and the most comprehensive diagnostic and treatment services in the San Diego region. An average of 2,318 ECGs per month were taken at this hospital in FY 1979 (X Period); this represented 32 percent of the volume of ECGs taken at facilities to be included in CAPOC in the Southern California area.

In calendar year 1980, San Diego NRMC averaged 2,002 ECGs per month, a decrease of 13.6 percent from 1979. This represented 32 percent of all ECGs done at facilities in the San Diego region that have (or will have) access to CAPOC.

In addition to those ECGs taken at the hospital, San Diego NRMC provides reading services for branch clinics. These six branch clinics that would have access to CAPOC averaged 918 ECGs per month in 1979. This number decreased slightly to 910 ECGs per month in 1980 for the same size branch clinics. This means that in 1979, 48.6 percent of all ECGs done in the Southern California area were interpreted at San Diego NRMC. This number decreased to 46.3 percent in the Y Period.

Because of its role in providing comprehensive patient care, and ECG services in particular, and its role as the central site in the CAPOC project, San Diego NRMC was a major data collection site for the evaluation.

San Diego NRMC consists of a large hospital and 12 branch clinics. Six of the branch clinics have (or will have) access to CAPOC. Data on these sites--one primary evaluation site and five secondary sites--are included in this report. This section discusses the activities at San Diego NRMC and those activities that are relative to the branch clinics.

San Diego NRMC has approximately 600 authorized beds in the hospital itself. The occupancy averaged 472 beds in 1979 and 463 beds in 1980.

In 1979 over 712,000 outpatient visits were recorded; this number rose to 886,000 in 1980. In total, the hospital and 12 branch clinics had 1.3 million outpatient visits in 1979 and 1.6 million in 1980.

The hospital staff included 479 physicians in 1979 and 488 in 1980. Residents and interns totaled 286 in 1979 and 282 in 1980. Total military personnel at San Diego NRMC were 1818 in 1979 and 1915 in 1980. The Cardiology Service included four cardiologists, two pediatric cardiologists, six fellows in cardiology, and from two to five residents and interns. Between 1979 and 1980 data collection periods, two cardiologists and one cardiology fellow left and were replaced by one cardiologist and two cardiology fellows. The cardiology staff shares the bulk of the ECG reading responsibilities. In this text the term "cardiologist(s)" refers to the staff of the Cardiology Service, including fellows and house staff, who read ECGs, unless otherwise specified.

The staff of the hospital of San Diego NRMC refers to the hospital only as "NRMC" in spite of the formal organization that includes the hospital plus 12 branch clinics. This report also refers to the hospital as San Diego NRMC and to the specific branch clinics if they are intended to be included in any discussion.

2. ECG Service Organization and Staffing

The Heart Station at San Diego NRMC is the primary focus for ECG services. The manual ECG process as observed in September of 1979 is shown in Figure 3-1. The average time for each part of the process is included in Figure 3-1. These values were obtained by direct observation. The process was initiated when a request for an ECG is filled out by a nurse or corpsman. If the patient was ambulatory[6] he proceeded with the request to the Heart Station.[7] At the Heart Station information was entered in a log and cover sheets were prepared and attached to the requisition.

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[6] 61.4 percent of ECG patients were ambulatory.

[7] The Heart Station operates from 0730-1130 and 1230-1630, Monday-Friday.

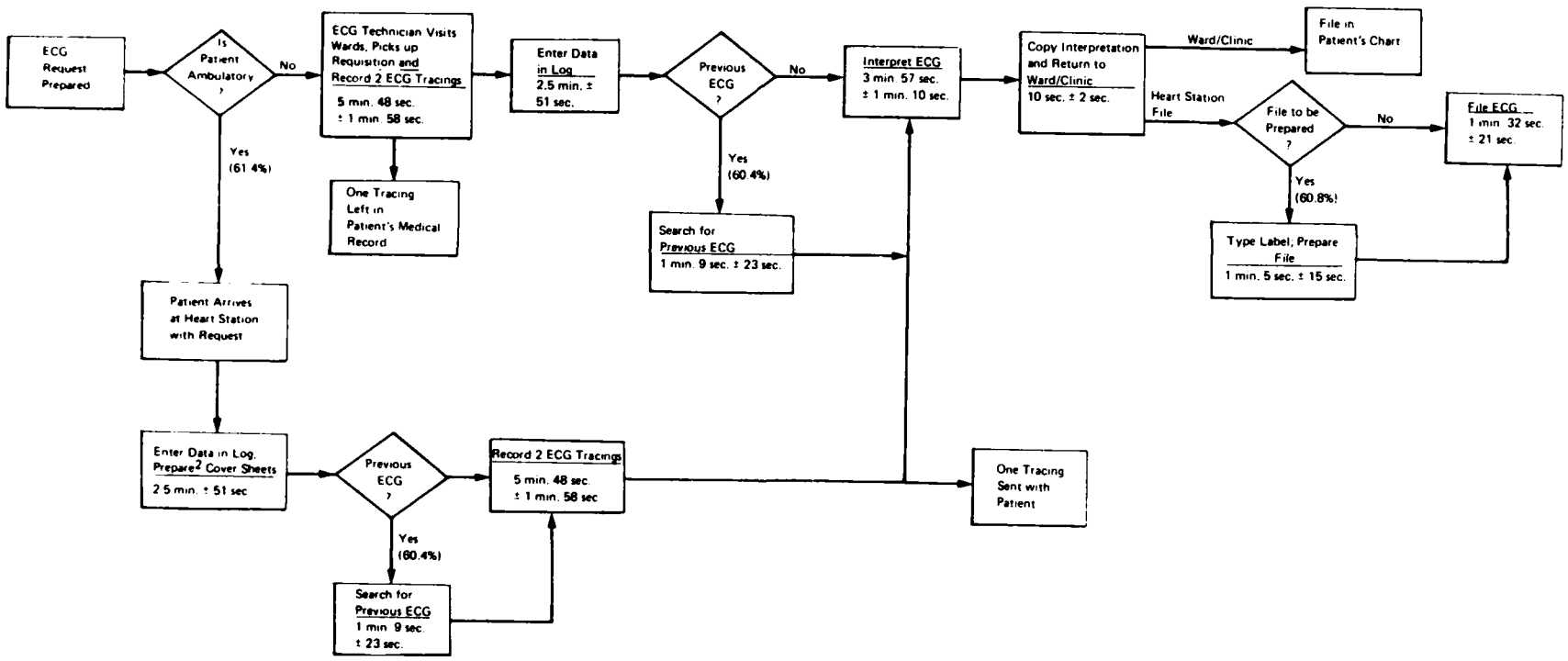

FIGURE 3–1 FLOWCHART OF THE ECG PROCESS AT SAN DIEGO NAVAL REGIONAL MEDICAL CENTER AND AVERAGE TIMES SPENT OR ELAPSED FOR INDIVIDUAL STEPS, SEPTEMBER 1979

The patient was asked if he had had a previous ECG at San Diego NRMC.[8] If the patient had had a prior ECG, the corpsman retrieved the old ECG(s) from the files maintained in the Heart Station. The ECG file was attached to the request and cover sheet and the patient's ECG was taken. Two tracings were made--one was given to the patient to take with him and the other kept in the Heart Station to be read.

Tracings were obtained for patients who were not ambulatory when a corpsman from the Heart Station made the rounds of the wards. For each ward the requests were found in a box at the nursing station. Two tracings were recorded; one was left in the patient's chart and one was brought to the Heart Station. There the technician entered the necessary data in the log, retrieved prior ECGs from the file, and then left the ECGs for reading.

ECGs were also taken in the Emergency Room and the intensive care units by the personnel assigned to these units. These tracings were given initial readings by the internist or cardiologist caring for the patient and then sent to the Heart Station to be logged in, formally read, and filed. STAT ECGs for inpatients were done by a corpsman from the Heart Station and were left in the patient's chart to be read by the requesting physician.

All ECGs for pre-operative patients were read by the cardiologist assigned to the Heart Station to perform readings that day; these ECGs were read after 1630 of the day the tracings were taken. The corpsman on duty was responsible for telephoning the interpretation to the appropriate ward that evening. He also recorded the patient's name and location and the ECG interpretation in the watch log. The personnel on the wards were responsible for writing the telephoned interpretation in the patient's chart. All other ECGs were read by the cardiologists who did the bulk of the reading the following morning. The interpretation was handwritten on the requisition form and signed by the cardiologist.

After the ECGs had been read, the handwritten interpretation was photocopied and returned via the mail to the location from which the

[8] 60.4 percent of patients who had had ECGs done in the Heart Station responded "yes" to this question.

patient came. Eventually this copy was filed in the patient's medical record. The original copy of the interpretation, along with the tracing, was filed at the Heart Station. A folder and label were prepared for those ECGs for patients with no prior tracing. The filing step completed the ECG process as it was in place during the X Period data collection in September of 1979.

Several changes have occurred as a result of CAPOC implementation at San Diego NRMC. The revised ECG process when CAPOC is fully implemented (i.e., automatic storage and retrieval) is shown in Figure 3-2. The relevant times observed during the Y Period data collection are presented in Figure 3-2. The following discussion highlights the changes in the process that have occurred as a result of CAPOC and were observed during the Y Period data collection effort.

For patients having ECGs in the Heart Station, the ECG technicians prepared one cover sheet instead of two. The log was kept only as a reference for any inquiries about patients being sent for an ECG. The log was a record of only the ECGs done in the Heart Station and was discarded at the end of the month. Previously, logs were kept for one year and were used to prepare the necessary reports to the Commanding Officer. All log data are now maintained by CAPOC.

The ECG technician made only one tracing in the Y Period, instead of two. This tracing remained with the patient while the ECG request was matched with the unconfirmed interpretation generated at the over-read site in the Heart Station. The time to obtain the ECG has not changed significantly since the time required for the additional tracing has been replaced by the time required to enter patient data in the system. The matching of the ECG request with the unconfirmed interpretation was a new activity resulting from CAPOC.

The ECG reading process remained unchanged. ECGs for pre-operative patients were read in the evening and the results called back to the floor. All other ECGs were read the next morning. Readers entered changes to the computer-generated interpretation by crossing out comments, adding standard comments using number codes, or adding free-form text comments. The reader put his "number" on the interpretation when he was finished.

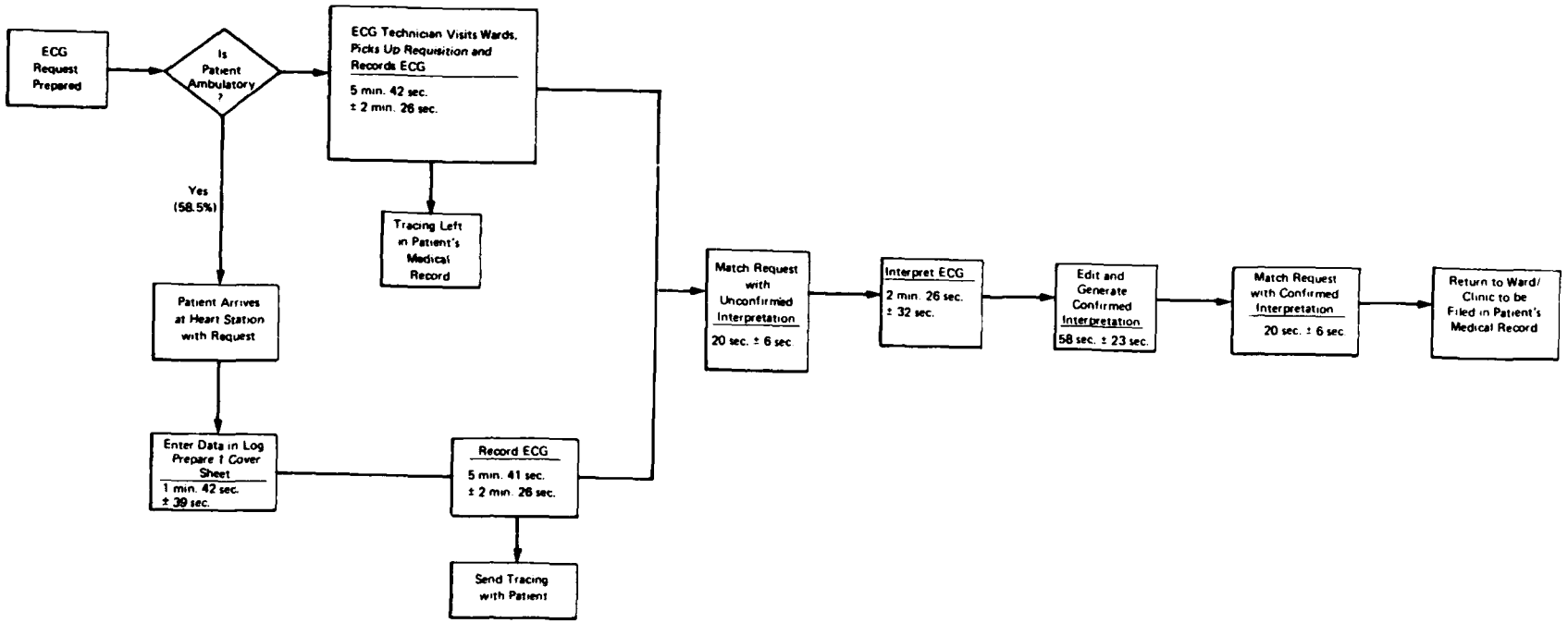

FIGURE 3–2 FLOWCHART OF THE ECG PROCESS AT SAN DIEGO NAVAL REGIONAL MEDICAL CENTER AFTER FULL IMPLEMENTATION OF CAPOC AND AVERAGE TIMES SPENT FOR INDIVIDUAL STEPS

Following the morning reading session, all ECGs were edited at the overread station in the Heart Station. For those ECGs done at San Diego NRMC, a copy of the tracing with the confirmed interpretation was generated. This ECG was matched with the ECG request and returned to the patient's medical record via the mail. ECGs from the branch clinic were edited and the confirmed interpretation was automatically forwarded to the branch clinic via a teleprinter.

In addition to the overread station in the Heart Station, there was an overread station in the Emergency Room. However, the high turnover rate in the ER meant that there was low utilization of the equipment due to the lack of training of personnel. Originally, the Coronary Care Unit also had an overread station, but this has been removed. ECGs taken in these locations are read by the requesting physician. ECGs from the CCU and Emergency Room are read by the cardiologists in the Heart Station. The only impact of CAPOC on these areas has been to increase the capture of ECGs for reading in the Heart Station. Previously, the personnel on the floors were relied upon to forward the ECGs via the mail and, presumably, some were lost and/or never sent.

In both X and Y data collection periods, the Heart Station was staffed by a mix of Navy Corpsmen (E-3 and E-4 levels) and two to four civilian technicians. The civilian technicians took ECGs and performed report editing.

The corpsmen were responsible for all ECGs done on the wards and those requested when the Heart Station was not open. The corpsmen also did other non-invasive tests such as stress tests and echocardiograms.

3. Quantitative Data Collection Methodology

Several different collection techniques and methods were utilized to collect evaluation data at San Diego NRMC. The data obtained included: reading volumes and times and specialty of reading staff, times for the ECG process, turnaround time, volume of ECGs done, and

distribution of normal/abnormal interpretations, patient location, and types [9] of ECGs.

a. Data on Volume and Type of ECGs

Volume data were collected by different methods in the X and Y Periods. In the X Period, data on ECG volumes were obtained by tallying the information from the log maintained in the Heart Station. Volume data for the Y Period were obtained from the computer logs. These tallies, coupled with data obtained during the data collection period, were used to derive the breakdowns in volume by type of ECG.

Information on the types of ECGs taken and read each morning was obtained following the reading of the ECGs and the copying of the interpretations; the observer recorded the following information: the log number, patient location, where the ECG was done (Heart Station or Ward), type (for annual physical, pre-operative patient, etc.), age, reader, interpretation (normal/abnormal), whether or not the patient had indicated that a previous ECG was available for a serial comparison, and if a prior ECG was available. This information was obtained from the requisition, the log, and the ECG file.

During the X Period data collection effort, it was noted that while 60 percent of patients indicated they had a prior ECG taken at San Diego, old tracings were located for only two-thirds of these. Since availability of prior ECGs is a requirment for abnormal ECGs in order to meet the evaluation criteria for serial comparison, this finding required further investigation. Three reasons for the lost ECGs were suggested: the patient might not actually have received the ECG, the file might have been lost, or the ECG might have been misfiled in the wrong patient folder or in the wrong order.

In order to investigate these possible reasons further, 80 ECGs were identified for which the patient replied that a prior ECG had been taken at San Diego but for which no old ECG file was found. For 38

[9] ECG types include: pre-operative ECGs, routine inpatient ECGs, STATs, ECGs done in the Emergency Room (ER), routine outpatient ECGs, and ECGs done as part of annual physical examinations.

(48 percent) of these, the researchers were able to locate the old file by searching through the files nearby the area where the file was supposed to be located. Therefore, misfiled records appear to be a large factor in explaining the number of prior "lost" ECGs.

b. Reading Time

Reading times and number read were obtained by observing ten of the reading sessions held each morning in the Cardiology Department. The observer recorded the length of time and the number of physicians reading. By dividing the total person-minutes of reading time by the total number of ECGs read, average reading times per ECG were obtained. An average reading time was recorded for each observation day and then an average and standard deviation were calculated for the entire observation period of 10 days.

c. Turnaround Time

In the X Period, two different methods were used to collect turnaround time[10] data. With the first method the log number, location, and time the ECG was taken were recorded. The next day after the ECG had been interpreted and inserted in the laboratory mail boxes, the boxes were checked every half hour in order to ascertain if the interpretations had been picked up by the ward or clinic personnel. The second method was to attach a form to the ECG. The form contained the ECG log number and the time the tracing was taken. The form contained a request that the nurse or corpsman who filed the interpretation in the patient's chart indicate date and the time of filing and return the form to the Heart Station. Turnaround time was collected for ECGs using these two methods.

[10] Turnaround time is defined as the time between the recording of the ECG and the return of the written interpretation to the appropriate ward or clinic. It is usually difficult to know the latter time exactly, so two different methods were used to approximate this time.

In the Y Period, the only method used was to attach forms to the ECGs. A total of 1,000 forms were attached to ECGs during the month of October. Of these, 193 were returned with sufficient information to determine turnaround time.

4. Quantitative Data Analysis

a. ECG Volumes

Monthly ECG volumes for San Diego NRMC are summarized in Table 3-1. The data for the X Period are reported for fiscal year 1979, i.e., October 1978 to September 1979. Since CAPOC was not fully operational in the first quarter of fiscal 1980, Y Period data are reported for the calendar year 1980. In the X Period, San Diego NRMC processed 27,818 ECGs or an average of 2,318 per month. These figures dropped to 24,032 and 2,002, respectively, in the Y Period. Because detailed logs of patient location were not available in the Y Period, only two places could be isolated for comparison - the Coronary Care Unit and the Emergency Room. The CCU volume decreased 31 percent from a monthly average of 313 to 220. The Emergency Room increased from 137 ECGs per month to 164 ECGs per month, an increase of 20 percent. This change may be due to differences in patient mix or number of patients seen. It may also be due to the elimination of unnecessary duplicate tracings caused by poor quality tracings or lost tracings. In the Y Period staff at San Diego NRMC felt that CAPOC had caused a reduction in the number of unnecessary repeat tracings. However, no quantitative data were available to evaluate the magnitude of this impact nor to estimate possible overreporting in the X Period.

TABLE 3-1

ECG VOLUMES FOR SAN DIEGO NAVAL REGIONAL MEDICAL CENTER

X Period (fiscal year 1979)		Y Period (calendar year 1980)	
October 1978	2361		
November	2182		
December	1881		
January 1979	2528	January 1980	2380
February	2365	February	2160
March	2753	March	1866
April	2860	April	1972
May	2303	May	1873
June	2380	June	2205
July	2025	July	2160
August	2058	August	1961
September	2033	September	1640
		October	2173
		November	1733
		December	1909
TOTAL	27818	TOTAL	24032

Data collected during the two data collection periods and data from logs were used to estimate breakdown by type of ECG. The breakdown of ECG by types for the two periods is shown in Table 3-2.

The increase in outpatient visits was reflected in the increase in the percentage of routine outpatient and annual physical ECGs. Admissions to the hospital were down slightly in 1980. The increase in emergency room ECGs may actually be due to more accurate reporting by the CAPOC system. Previously, only ECGs that were sent to the Heart Station by the emergency room staff were entered in the log and counted. With CAPOC, all ECGs done in the emergency room were recorded.

b. Service Effectiveness Impacts

The distribution of volume read by cardiologists, internists, and other physicians is shown in Table 3-2, along with the breakdown of the volume according to normal and abnormal interpretation. These data have been combined with measured turnaround time in Table 3-3, which summarizes the resulting service effectiveness for the X Period, Y Period, and projected full implementation of CAPOC.

In the X Period, 57.4 percent of all ECGs met criteria for effective services (acceptable plus preferred). In the Y Period, this number dropped to 13.4 percent. Two areas can be identified as the cause of this drop. Serial comparisons were only done for 3.2 percent of all abnormal ECGs in the Y Period, down from 49.2 percent in the X Period. Since implementation of CAPOC in October 1979, the Heart Station had stopped keeping copies of ECGs. In addition, all files for patients that have not had an ECG within the last two years were discarded. (This practice was in existence prior to CAPOC.) These two events meant that ECGs were only available for patients whose last ECG was in fiscal year 1979. Thus, files were only pulled for these

TABLE 3-2

SUMMARY OF QUANTITATIVE DATA FOR
SAN DIEGO NAVAL REGIONAL MEDICAL CENTER

	X Period	Y Period
Volume	27,818	24,032
Type		
Routine Outpatient	33%	38.0%
Annual Physical	3%	5.0%
Routine Inpatient	42%	31.5%
Pre-Operative	15%	13.5%
STAT/ER	7%	12.0%
Reader		
Cardiologist	83.2%	88%
Internist (or Resident)	16.8%	12%
Other	0	0
Interpretation		
Normal	41.5%	36.9%
Abnormal	58.5%	63.1%

TABLE 3-3

SUMMARY OF IMPACTS OF CAPOC ON EFFECTIVENESS OF ECG SERVICES
AT SAN DIEGO NAVAL REGIONAL MEDICAL CENTER

	Number of ECGs (Percent)		
	X Period	Y Period	Full Implementation
Reader			
Preferred	23,145 (83.2)	21,739 (90.5)	21,739 (90.5)
Acceptable	4,673 (16.8)	2,293 (9.5)	2,293 (9.5)
Turnaround Time			
Preferred	9,542 (34.3)	4,509 (18.8)	13,633 (56.7)
Acceptable	13,158 (47.3)	4,473 (18.6)	2,830 (11.8)
Abnormals with Serial Comparison	8,012 (49.2)	481 (3.2)	12,133 (80.0)
Conclusion			
Preferred	4,534 (16.3)	1,442 (6.0)	10,838 (45.1)
Acceptable	11,434 (41.1)	1,778 (7.4)	4,085 (17.0)
TOTAL	15,968 (57.4)	3,220 (13.4)	14,923 (62.1)

patients. Patients who had had ECGs since October, 1979, did not have copies of prior tracings because the automatic storage and retrieval program was not in operation and Heart Station personnel did not do manual retrievals from the CAPOC system. The other impact was an increase in measured turnaround time, resulting in a decrease in the percent of ECGs meeting this criterion. However, since the X Period sample size was very small, this change may not be significant. Rather, it may be due to the increased number of ECGs tracked in the Y Period.

Full implementation could result in 62.1 percent of all ECGs meeting effective criteria. For this to be achieved, several changes must occur. The primary change is the availability of automatic storage and retrieval of prior ECGs. When this capability is installed, it is estimated that 80 percent of all abnormal ECGs will have a prior tracing available for a serial comparison. Secondly, it would require that all pre-operative ECG reports be returned to the wards the evening before surgery instead of the results being telephoned back. It would also require that patients sent to the Heart Station for an ECG be given a copy of the unconfirmed report to take back to the requesting physician. This would result in all normal ECGs having a preferred turnaround time.

c. Sensitivity Analysis of Effectiveness Impacts

A sensitivity analysis was performed in order to investigate the possible effects of errors in Y Period data and the impacts of policy changes on service effectiveness. If the turnaround times in the Y Period had remained unchanged from the X Period, the level of effective ECG service would have been 32 percent. The decrease can be attributed to a lack of serial comparisons for abnormals (63 percent of the volume). If the computer-generated interpretation for a normal ECG had been given to the patient and pre-operative ECGs had been returned to the floors in the evening, the effectiveness would have been 38 percent. The lack of serial comparison is the key factor in the decrease in service effectiveness between the X and Y Periods.

5. Analysis of Qualitative Data

Staff questionnaires were distributed at San Diego NRMC during both the X and Y Periods. In the X Period, 52 completed questionnaires were returned by physicians and 18 were returned by nurses/corpsmen and ECG technicians. In the Y Period, 90 physician questionnaires and 17 questionnaires from nurses/corpsmen and ECG technicians were completed; 70 of the physician respondents and 7 of the other staff were on the staff of San Diego NRMC during both X and Y Periods. This section discusses staff perceptions of ECG services, focusing on changes that resulted from the implementation of CAPOC.

a. Physician Questionnaires

i. ECG Functions

Virtually all physician respondents in both periods reported that they order ECGs and read them for their own patients. (These staff are referred to as "users" in this discussion.) Approximately 40 percent perform overreading functions, either by interpreting ECGs for patients treated by others or by checking ECG interpretations done by others. Physician respondents reported that their role in the ECG process was unchanged by CAPOC. Therefore, the respondent base is assumed to have had similar knowledge of the ECG process in X and Y Periods.

ii. Service Response Times

Figures 3-3 through 3-7 compare the distribution of X and Y Period responses regarding acceptable service response times for STAT and routine ECG services. (Note that the respondent base for the two periods was 52 and 90, respectively, so that the distribution rather than the number of responses is significant.) For both X and Y Periods, these responses correlated well with the evaluation criteria for turnaround time developed for this evaluation. Most of the respondents believed that an interpreted

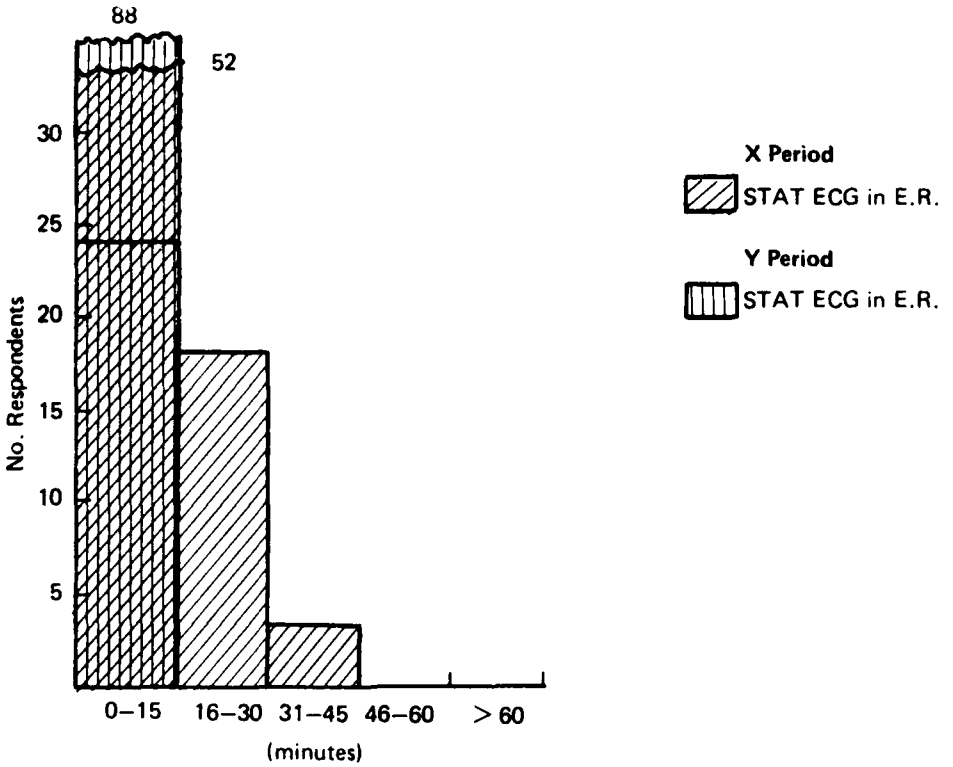

FIGURE 3–3 ACCEPTABLE DELAY BETWEEN REQUEST FOR STAT ECG AND TIME IT IS TAKEN IN THE EMERGENCY ROOM – PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT SAN DIEGO NAVAL REGIONAL MEDICAL CENTER – X AND Y PERIODS

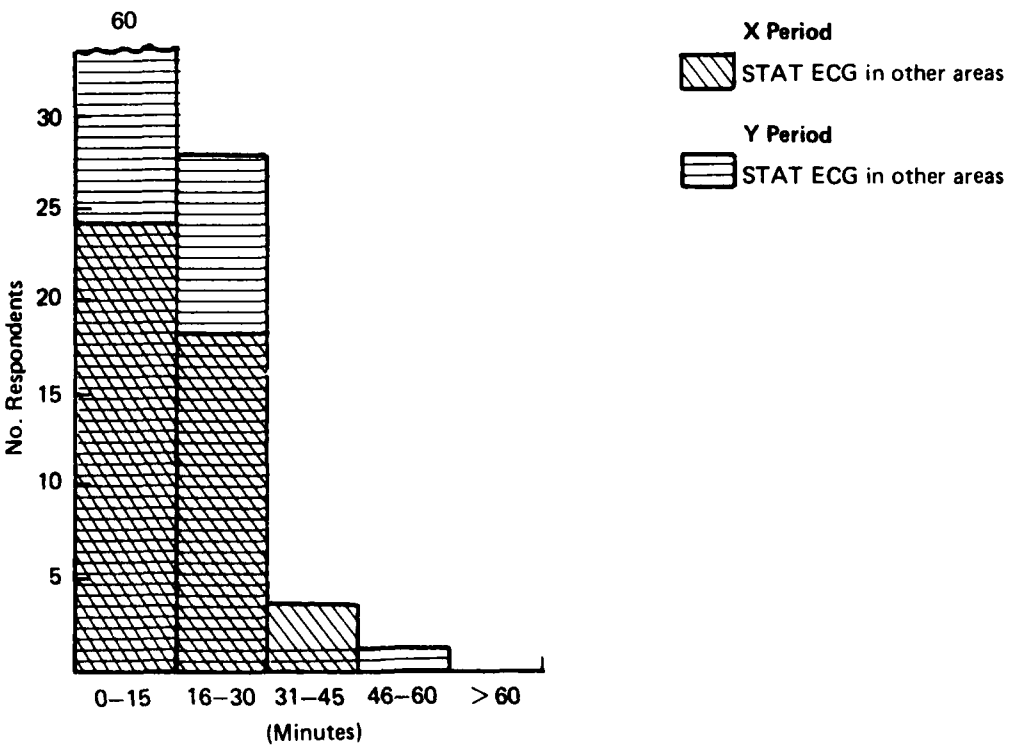

FIGURE 3–4 ACCEPTABLE DELAY BETWEEN REQUEST FOR STAT ECG AND TIME IT IS TAKEN IN OTHER AREAS – PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT SAN DIEGO NAVAL REGIONAL MEDICAL CENTER – X AND Y PERIODS

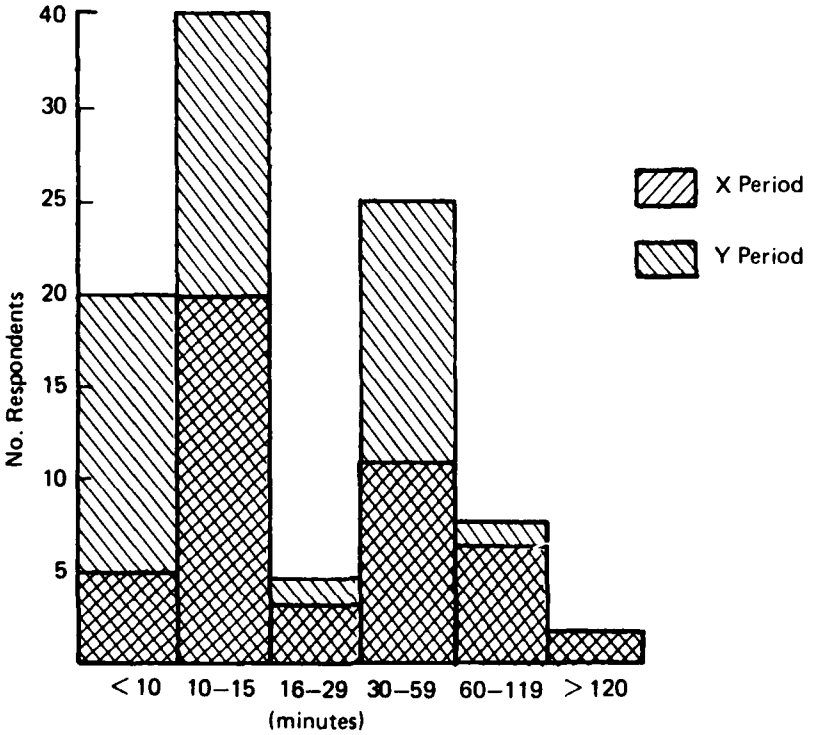

FIGURE 3–5 ACCEPTABLE DELAY BETWEEN REQUEST FOR STAT ECG AND AVAILABILITY OF INTERPRETATION– PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT SAN DIEGO NAVAL REGIONAL MEDICAL CENTER – X AND Y PERIODS

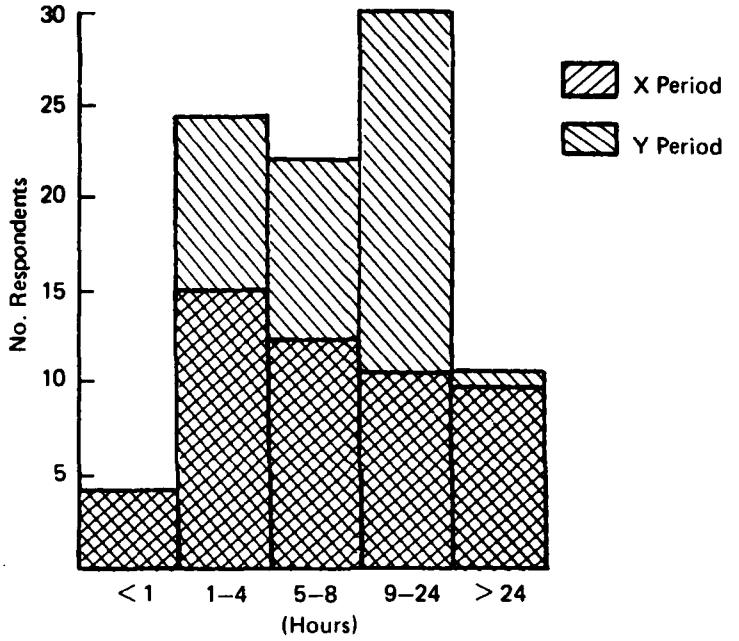

FIGURE 3–6 ACCEPTABLE DELAY BETWEEN REQUEST FOR ROUTINE ECG AND TIME IT IS TAKEN–PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT SAN DIEGO NAVAL REGIONAL MEDICAL CENTER – X AND Y PERIODS

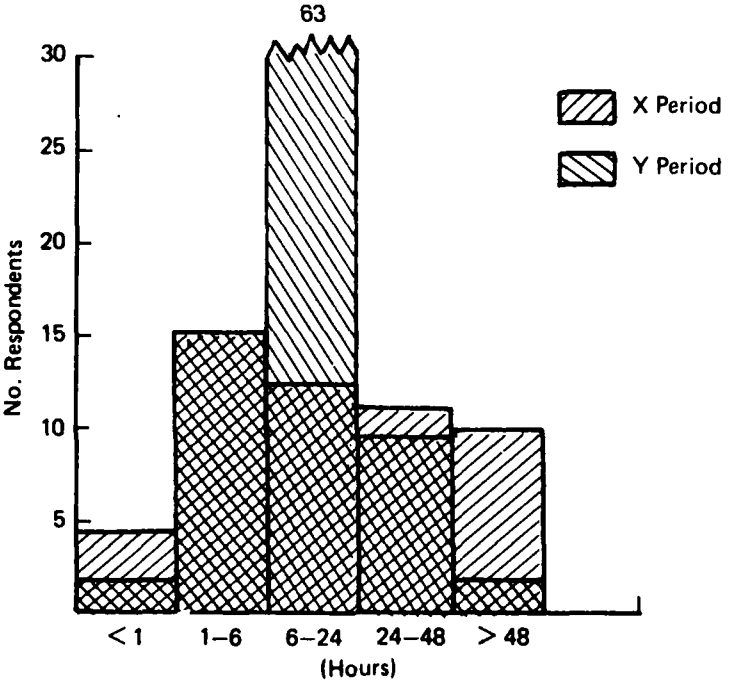

FIGURE 3–7 ACCEPTABLE DELAY BETWEEN REQUEST FOR ROUTINE ECG AND AVAILABILITY OF INTERPRETATION–PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT SAN DIEGO NAVAL REGIONAL MEDICAL CENTER – X AND Y PERIODS

STAT ECG should be available within 30 minutes and than an interpreted routine ECG should be available within 24 hours.

iii. Implementation Status

In the Y Period, physicians were asked about the frequency and circumstances of manual ECG processing. Nearly two-thirds were unaware of these aspects of the ECG services. Of the remainder, most reported that manual ECGs are done almost every day (2) or at least once a week (6). The reason most often cited was unavailability in areas where ECGs are taken (29 responses), CAPOC not available (21) or not working (15), and CAPOC system too busy. Six respondents felt that the manual system was more satisfactory, citing response time (especially for emergencies). (This response was not surprising in that the primary care physicians usually do not have even the unconfirmed, computer-generated interpretation when they see their patients. In both periods, these physicians received a tracing with no labeling or an interpretation, unconfirmed or otherwise. Interviews with staff confirmed that many are not even aware of CAPOC because interpretations reach the patient chart or record several days later.)

iv. Attributes of ECG Services

Figure 3-8 displays the results derived from the portion of the staff questionnaire concerning the importance of certain attributes of ECG services and the degree of satisfaction with the performance of the current ECG system. In order to provide a basis for comparison, responses have been weighted as follows:

Importance Rating		Satisfaction Rating		Rating Value
Very important	1	Very satisfied	1	+2
	2		2	+1
	3		3	0
	4		4	-1
Very unimportant	5	Very dissatisfied	5	-2

The sums of all weighted responses to each question are displayed in Figure 3-8 for the X and Y Periods. The data have been normalized so that the maximum possible positive or negative score is 100.

The cumulative ratings concerning the importance of ECG service attributes are shown on the left-hand side of Figure 3-8; those concerning satisfaction with the current ECG system appear on the right-hand side.

As can be seen, importance ratings assigned by physicians to the various attributes were fairly consistent in the X and Y Periods. Two exceptions to this general pattern were the importance of 24-hour availability of STAT interpretations and consistency of ECG readings among readers. No reasons related to CAPOC implementation were identified to account for these differences.

Satisfaction ratings increased somewhat for the response times for STAT ECG tracings and interpretations and 24-hour availability of tracings, and also for the availability of routine ECG tracings. Overall ratings decreased for accuracy (see also below) and completeness of interpretations and the availability of serial comparisons and experts to aid in patient management. Satisfaction with the technical quality of tracings increased by 30 percent. Ratings for all other service attributes remained essentially unchanged.

When asked specifically about changes in ECG services resulting from CAPOC, many respondents believed that most aspects of ECG services had not changed due to CAPOC. Of those who believed they had sufficient exposure to CAPOC to comment on changes, many cited improvements in the availability of STAT ECG (39%) and routine interpretations (35%), the turnaround times for STAT (42%) and routine (43%) interpretations, and the accuracy (33%) and completeness (50%) of interpretations. Large numbers of those who commented, cited improvements in the technical quality of tracings (57%) and ease of reading and understanding interpretations (65%). A decrease in service quality was reported by 55% of those who commented on the number of diagnostic and treatment areas where ECGs can be interpreted.

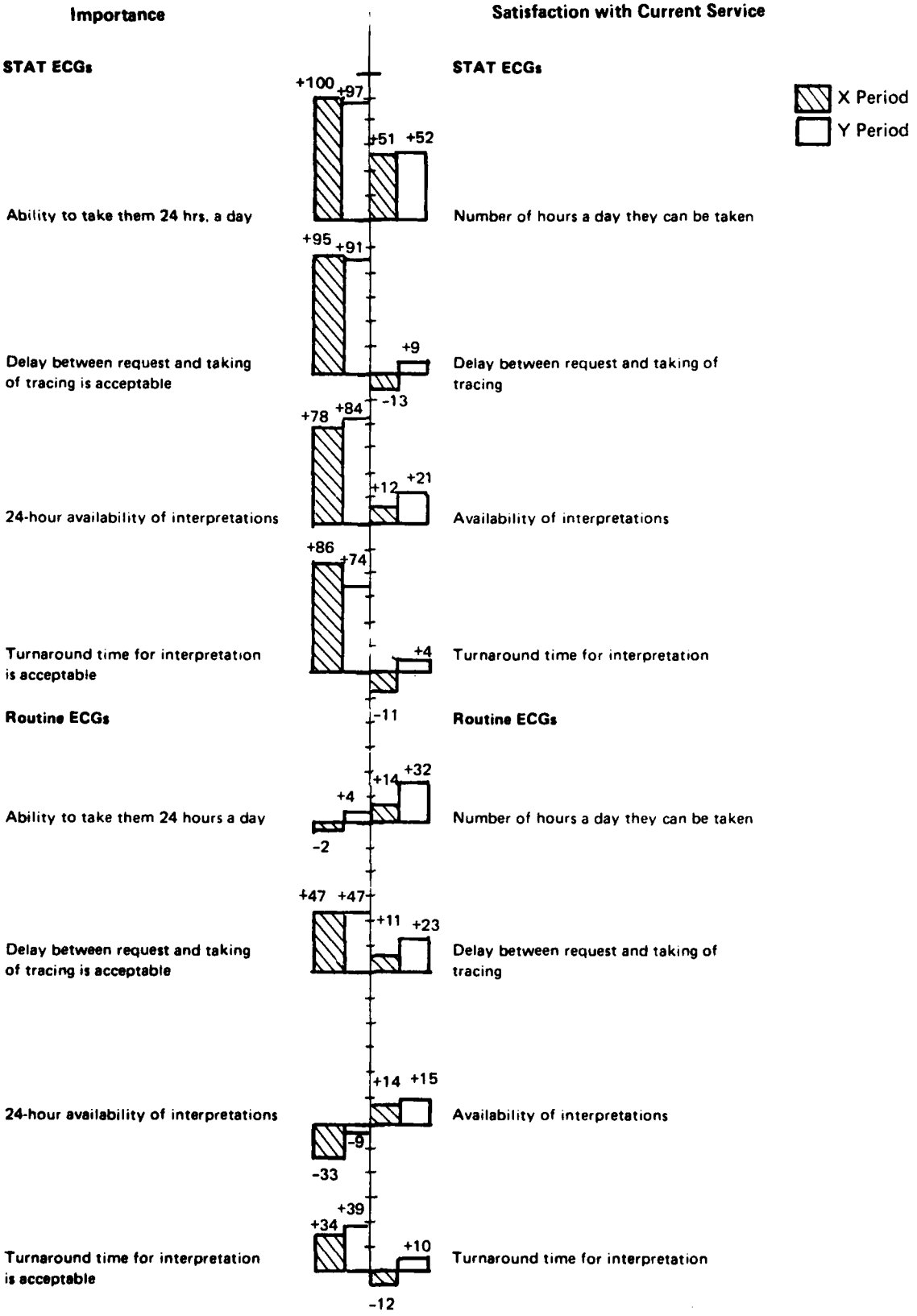

FIGURE 3–8 CUMULATIVE RATING OF ECG SERVICE ATTRIBUTES – PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT SAN DIEGO NRMC, X AND Y PERIODS

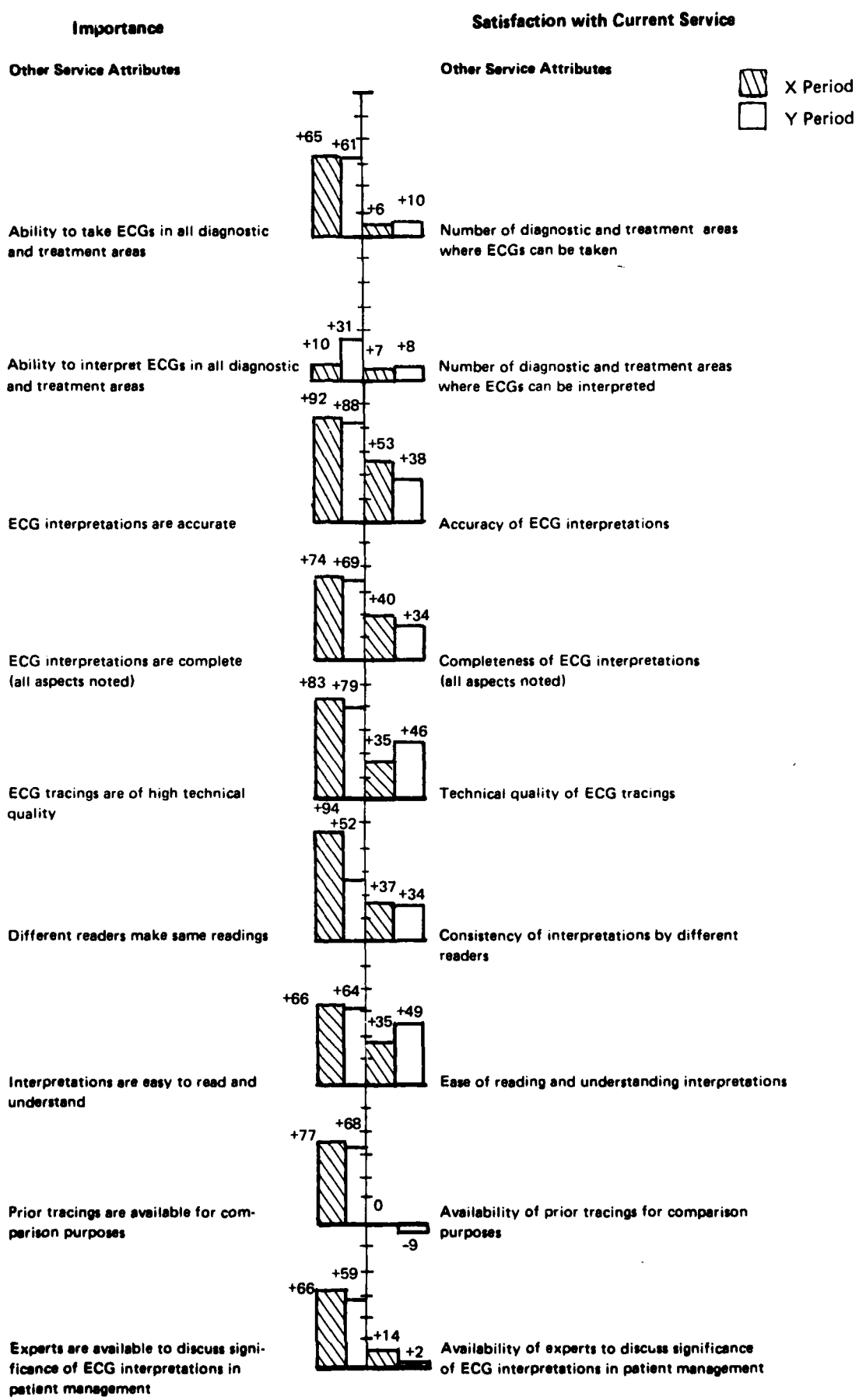

FIGURE 3–8 (continued)

v. Accuracy

Table 3-4 summarizes the responses of all users and readers regarding the accuracy of CAPOC interpretations for eight categories of ECGs. They generally placed more confidence in CAPOC readings of normal than abnormal ECGs. For abnormal ECGs, they believed CAPOC readings were more accurate in identifying ST-T wave abnormalities, hypertrophy, and conduction abnormalities than in detecting rhythm abnormalities and myocardial infarctions.

Twenty-four readers and nine users reported that computer errors tended to be false positive results; four readers and four users believed that false negative results were more likely; and the remainder did not know.

vi. Reading Times

Figures 3-9 through 3-11 display the distribution of responses regarding reading times in the X and Y Periods. As indicated, physician perceptions of their average reading times increased for normal ECGs, decreased for abnormal ECGs, and were unchanged for serial comparisons.

Most (57%) of the physicians who had been on the staff before CAPOC was installed reported that no changes had occurred in the time required to read/interpret ECGs each week. Readers (who read the largest ECG volumes) were more likely to report that they spent less time (34% vs. 6%). (This is consistent with the measured decrease in reading times.) Physicians spending less time cited computer measurements, legibility of the CAPOC report, and less time for writing the interpretation. Those who felt that CAPOC was not saving time mentioned most often the lack of a computer interpretation in time to be useful or the need to check ECGs anyway.

vii. Recalls/Referrals

All of the 35 physicians at San Diego NRMC before CAPOC and after who were aware of the number of patients recalled for duplicate tracings

TABLE 3-4

ACCURACY OF CAPOC COMPARED WITH MANUAL ECG INTERPRETATIONS, OPINIONS OF PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRES AT SAN DIEGO NRMC

	Relative Accuracy of ECG Reading (Percent of Respondents)								
	CAPOC More Accurate			No Difference			Manual More Accurate		
Type of ECG	Users*	Readers*	All Respondents	Users	Readers	All Respondents	Users	Readers	All Respondents
All ECGs	53	48	50	27	31	30	20	21	20
Normal ECGs	60	42	48	40	55	50	0	3	2
All Abnormal	36	33	34	35	27	30	29	40	36
Rhythm Abnormalities	43	23	30	14	27	22	43	50	48
Myocardial Infarctions	34	28	29	33	38	37	33	34	34
ST-T Wave Abnormalities	50	47	45	36	33	35	14	23	20
Hypertrophy	50	38	42	21	28	25	29	34	33
Conduction Abnormalities	43	45	44	21	17	19	36	38	37

* Users are physicians who order ECGs to be taken on their patients and/or interpret ECGs for their own patients. Readers are physicians who interpret ECGs for patients treated by others and/or check ECG interpretations done by others. The respondent sample included 70 physicians who had been on the staff at San Diego NRMC prior to the installation of CAPOC. The number of respondents expressing an opinion on each question varied slightly. The respondent base for each question included 29 to 31 physician readers and 14 to 15 physician users. Other respondents expressed no opinion or indicated they did not know.

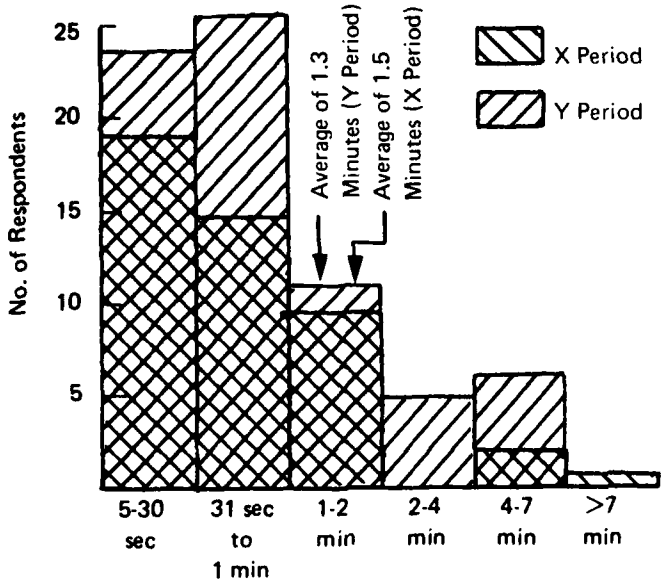

FIGURE 3–9 ESTIMATED TIME REQUIRED TO READ A NORMAL ECG – PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT SAN DIEGO NAVAL REGIONAL MEDICAL CENTER – X AND Y PERIODS

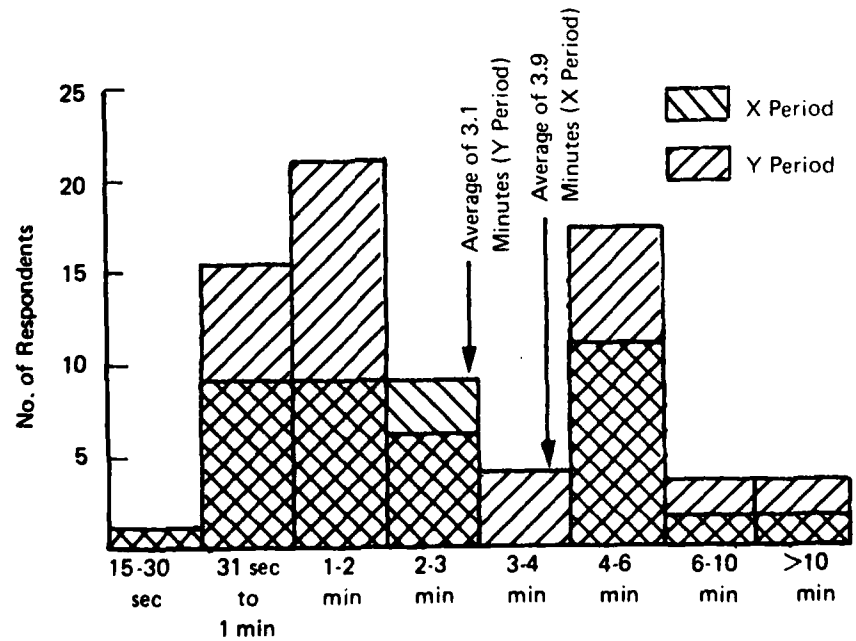

FIGURE 3–10 ESTIMATED TIME REQUIRED TO READ AN ABNORMAL ECG – PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT SAN DIEGO NAVAL REGIONAL MEDICAL CENTER – X AND Y PERIODS

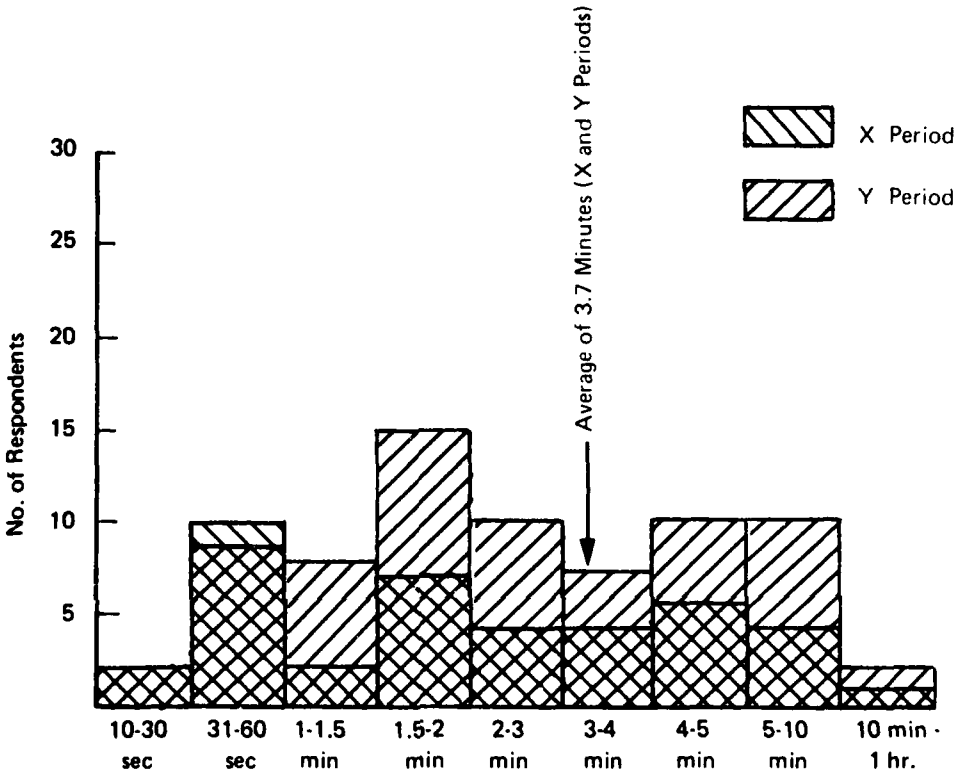

FIGURE 3–11 ESTIMATED TIME REQUIRED TO MAKE A SERIAL COMPARISON WITH A PRIOR ECG TRACING – PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT SAN DIEGO NAVAL REGIONAL MEDICAL CENTER – X AND Y PERIODS

reported that patient recalls due to a poor quality tracing had decreased since CAPOC (the remainder did not know). Similarly, they all reported that patient recalls due to lost tracings had decreased (again the remainder did not know).

Only 19 physicians felt they had direct knowledge of off-base referrals for cardiology expertise before and after CAPOC. Of these, 12 reported that referrals were unchanged, five that referrals had increased, and two that they had decreased. (Between the X and Y Periods, visits to the Cardiology Clinic increased by 3 percent.)

viii. Other Comments

When asked for an overall assessment of CAPOC, physicians responded as follows:

	Users	Readers
Extremely satisfied	1	4
Very satisfied	9	17
Fairly satisfied	18	19
Somewhat unsatisfied	5	3
Very unsatisfied	-	2
Do not know	9	3

Respondents were also provided an opportunity to comment in general about ECG services. Several commented that CAPOC should be made more available in primary care areas and/or that there was insufficient and outdated ECG equipment in areas of high patient concentrations. Other recurring comments included unavailability of the unconfirmed CAPOC interpretations and the delay before the confirmed interpretations reach patient charts.

b. Nurses and ECG Technicians

The analysis of the perceptions of other staff of ECG services before and after CAPOC has been focused on those aspects of [illegible]

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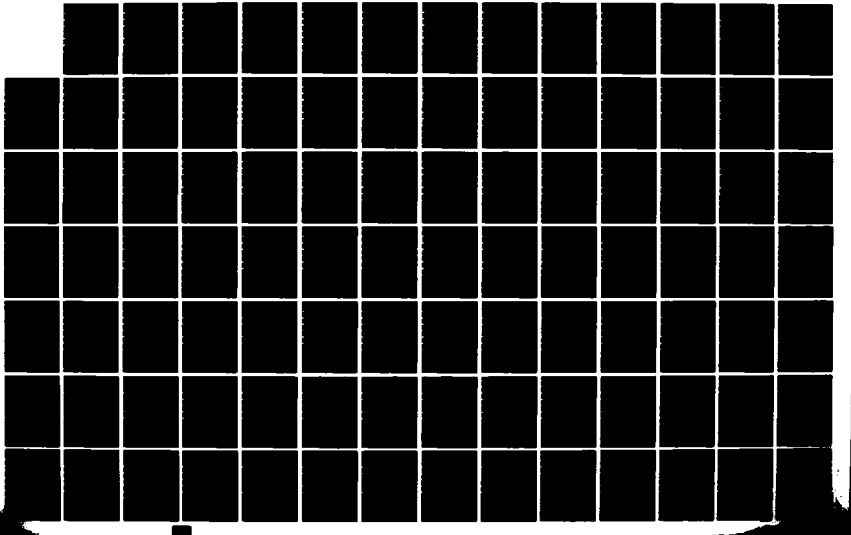

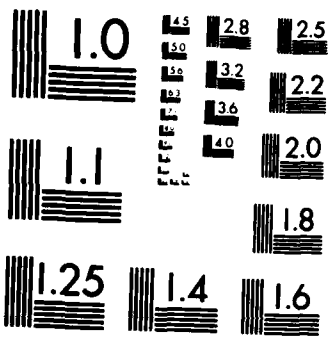

into which they have some unique insight (primarily quality of tracings and patients recalled for repeat tracings) and on the responses of the ECG technicians who work in the Heart Station and thus were interacting directly with the CAPOC system.

Five corpsmen, all of whom worked in the Heart Station, completed staff questionnaires. They rated their overall satisfaction with CAPOC as follows:

Extremely satisfied	1
Very satisfied	1
Fairly satisfied	3
Somewhat unsatisfied	0
Very unsatisfied	0

Specific advantages cited included automated storage and retrieval (elimination of filing of ECGs)[11], reduced paperwork, and general efficiency and quality of service. Two who were only fairly satisfied cited malfunctions of the portable ECG equipment and "system flaws" remaining to be overcome.

The corpsmen reported general satisfaction with accuracy, completeness, and consistency of interpretations as provided by the CAPOC system. Likewise, they were very or fairly satisfied with the technical quality of the tracings, the ease of reading and understanding interpretations, and the availability of prior tracings for serial comparisons. The only corpsman who had worked at the Heart Station before CAPOC was introduced reported that CAPOC had improved accuracy, consistency, completeness, and understandability of interpretations and the turnaround time for routine ECG interpretations. This same corpsman reported no change in patient recalls due to lost ECG reports or inadequate tracings. (The others did not comment.)

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[11]This feature was available for a short time, then removed until it could be adapted to the patient identification system within the military.

The 12 nurse respondents rated their overall satisfaction with CAPOC as follows:

Extremely satisfied	0
Very satisfied	4
Fairly satisfied	5
Somewhat unsatisfied	0
Very unsatisfied	0
Do not know	3

Specific advantages cited were improved service response times (although one nurse felt that turnaround times for STAT ECGs were still too long) and service availability. One nurse pointed out that the CAPOC interpretation is attached to the ECG tracing and, therefore, would not become separated or lost. Two nurses cited system malfunctions, in one case particularly the problems of using 12-lead ECG equipment.

The nurses reported general satisfaction with the number of hours a day STAT ECGs can be taken with the CAPOC system, the technical quality of tracings, and the ease of reading and interpreting ECG reports, as provided by the CAPOC system. They were generally dissatisfied with the turnaround time for routine ECG interpretations and the availability of serial comparisons. One respondent wrote in that the availability of the pre-operative ECGs was very unsatisfactory. For other system attributes, the responses were mixed.

Six nurses commented on the impact of CAPOC on ECG services. There was no unanimity of opinion on any individual aspect of ECG services. However, two believed that access to ECG services in some diagnostic and treatment areas had declined and three believed that accuracy and completeness of readings had declined. Three believed that ease of reading and understanding ECG reports had improved, and two reported better technical quality of ECG tracings.

6. Conclusions

Overall ECG service effectiveness at San Diego NRMC was 57 percent using manual methods. At the time of Y Period data collection, it had decreased to 13 percent. The decrease was caused by a lack of serial comparisons for the large volume of abnormal ECGs read at the facility. The effectiveness is expected to increase to 62 percent when automatic storage and retrieval is available and when several operational changes are instituted. CAPOC will result in a change in the percent of ECGs meeting preferred service criteria. Physicians at San Diego NRMC feel that there has been an increase in the quality of tracings and ease of interpretation. A decrease in lost ECGs was also noted as a benefit of CAPOC.

Twenty-three of 29 physician ECG readers surveyed about the relative accuracy of manual and computer-assisted interpretations for all types of ECGs found that CAPOC was as accurate as manual reading; 30 of 31 respondents reported that the accuracy of the computer equalled or exceeded the accuracy of manual reading of normal ECGs. Most reported that computer errors tended to be false-positive results (calling a normal ECG abnormal).

B. CAMP PENDLETON NAVAL REGIONAL MEDICAL CENTER

1. Introduction

Camp Pendleton NRMC consists of a main hospital, two small branch hospitals--Twentynine Palms and Barstow--and 14 clinics. This section discusses the ECG services at the main hospital and some information on the branch clinics. ECG services at Twentynine Palms and Barstow are discussed in detail elsewhere in this report.

The physician staff of the hospital at Camp Pendleton included one cardiologist and nine internists. These staff shared the responsibility for reading ECGs. Camp Pendleton had the second largest volume of ECGs in the region. They accounted for 14 percent of the volume in 1979 (the X Period evaluation) and 16 percent in 1980 (the Y Period evaluation).

The 185-bed main hospital had an average of 156 occupied beds, during this study, with an average length of stay of 5.5 days. It served a population of active-duty military personnel numbering 22,000 and a large population of retired personnel and dependents. Approximately 45 percent of the inpatient census is accounted for by active-duty personnel.

The hospital was opened in 1974 and has modern facilities and equipment. If needed, the facility could have a maximum capacity of 600 beds. Presently, space not being used for inpatient care has been converted to offices, laboratories, and outpatient clinics.

At the time of the Y Period data collection, CAPOC was not fully operational at Camp Pendleton. There were only two ECG carts that could transmit ECGs to the computer. These carts were used for part of the ECG volume--routine outpatient ECGs, pre-operative ECGs, and ECGs as part of annual physicals. Transmission problems were also interfering with the use of the CAPOC system. As a result of these limitations, only 30 percent of the total ECG volume was being captured by CAPOC during the fall of 1980 when Y Period data were collected.

2. ECG Service Organization and Staffing

The ECG Laboratory at Camp Pendleton, located in the Internal Medicine Department, took approximately one-half of all ECGs done at the hospital. The overall ECG process has not been changed by CAPOC.

For ECGs done in the ECG Laboratory, the following procedures were observed at the time of both site visits. Ambulatory patients were referred from various clinics. They brought an ECG requisition, which they left in a box at the appointment desk within the Internal Medicine Department. On a first-come, first-served basis, the ECG corpsman called patients from the waiting room and took their ECG. The corpsman then recorded the necessary patient information and retrieved the prior ECG file when one was available. ECGs for routine ambulatory patients were nearly all taken during the morning on Monday through Friday at the rate of about five ECGs per hour with two ECG corpsmen sharing one three-channel ECG cart.

For most non-STAT ECGs, the corpsman clipped the tracing to the requisition form and to the file folder (containing prior ECGs when available) and dropped these in a box in the ECG Laboratory. At the end of the morning, these were sorted into the mail boxes of the cardiologist and internists for reading.

Exceptions to this process were observed for some types of ECGs as follows:

- Internal Medicine Clinic ECGs--the ECG might be returned immediately to the ordering physician who might interpret the ECG before the patient left the clinic;
- pre-operative ECGs were sorted separately so that they would be certain to be read that day;
- STAT ECGs were given to a reader immediately for interpretation;
- pediatric ECGs were sent back with the patient to the clinic. These might be held for Pediatric Cardiology Clinic, which was held monthly, or they might be sent to San Diego NRMC to be read by a pediatric cardiologist; and

- branch clinic patients might have taken the ECG, with or without interpretation, back to the attending physician at the branch clinic.

The corpsmen in the ECG Laboratory took STAT ECGs in most areas of the hospital between 0800 and 1700 Monday through Friday. The corpsman usually returned to the Internal Medicine Department with the tracing, brought the ECG to a physician for reading, and then telephoned the interpretation back to the ward. Routine inpatient ECGs on non-ambulatory patients were usually taken during the afternoons. Usually two ECG copies were made: a ward copy was left in the patient's chart and another copy was brought back for interpretation and submitted for reading via the mail box as described above.

ECGs were also taken by corpsmen assigned to the Intensive Care Unit, other inpatient units, outpatient clinics, or branch clinics. These ECGs might be hand-delivered or mailed to the ECG Laboratory for reading. For inpatients, the tracings were often not sent to the ECG Laboratory until after the patient had been discharged; the staff in the Medical Records Department found the unread tracings in the patient's chart and mailed them to the ECG Laboratory.

After the ECGs had been read, a photocopy was made of the ECG and interpretation for the ECG file. The originals were returned to the requesting location. For wards and clinics in the hospital (except Internal Medicine Clinic), the ECGs were sorted into the clinical laboratory mail boxes. The staff of each unit was responsible for checking the mail box for all laboratory results. Pre-operative ECGs were hand-delivered to the wards by the ECG corpsman at the end of each day at around 1700. Mail to branch clinics was distributed via Guard Mail, which could add 1 to 7 days to the turnaround time, depending upon the location of the clinic and the mail schedule for that clinic.

In the X Period, the ECG equipment at Camp Pendleton consisted of three three-channel transmitting carts and five single-channel carts. Between the X and Y Periods, one of the three-channel transmitting carts was sent to Twentynine Palms Marine Corps Base Branch Hospital, leaving only two at Camp Pendleton. Equipment for overreading computer-generated ECG interpretations was located in the ECG Laboratory.

3. Quantitative Data Collection Methodology

Because of the low utilization of CAPOC (due to equipment and transmission problems) at Camp Pendleton, Y Period data collection was limited to interviews and a survey of staff to ascertain the status of ECG services.

X Period data at Camp Pendleton were collected principally using two techniques:

(1) a data collection form for tracking individual ECGs through the ECG process and for collecting data to allow comparison with ECG service criteria, and

(2) log books for collecting additional information on volumes and types of ECGs.

Ninety-two ECGs taken during a one-week period were followed from the time they were taken until the time that they were interpreted and either seen by the attending physician or were available for the physician (defined as the time the ECG is returned to the requesting location). In all, 91 of the 92 ECGs were tracked completely through this cycle.

In order to complete the data collection forms, the researcher:

(1) observed the time that each ECG was taken,

(2) recorded patient information and ECG type from the requisition and Log Book,

(3) noted whether an ECG file had been retrieved,

(4) observed either the time the ECG was interpreted or an approximate reading time (e.g., the time that the interpreted ECG was returned to the ECG Laboratory),

(5) noted the reader and the interpretation of the ECG,

(6) noted the time that the ECG and interpretation were mailed, and

(7) called or visited hospital staff at the requesting site to learn when the ECG was returned. This process was only done for ECGs taken by the ECG Laboratory corpsmen.

In order to find information on ECGs done elsewhere at Camp Pendleton, the Log Book was reviewed for one month's entries in order to learn how many ECGs were sent for reading. During the one-week period, the ECGs that were sent in for reading were studied for turnaround time. The date that these tracings were received was compared with the date they were taken in order to estimate turnaround time.

4. Quantitative Data Analysis

a. ECG Volumes

The X Period ECG volume at Camp Pendleton averaged 1,000 ECGs per month. Y Period ECG volume was estimated to be the same. The distribution by type of ECG for both periods is given in Table 3-5.

b. Service Effectiveness Impact

The measured distribution of ECG volume according to the medical specialty of the reader and the classification of the interpretation (normal or abnormal) are given in Table 3-5. These findings are combined with the results for turnaround time in Table 3-6, which summarizes the levels of ECG service effectiveness at Camp Pendleton for the X and Y Period and for full implementation of CAPOC. The overall level of ECG service effectiveness remained at 27 percent for both the X and Y Periods. The level of preferred services, however, increased from 1 percent to 6 percent of the ECG volume between the two periods. The lack of change in measured service effectiveness can be explained by the low level of CAPOC utilization at this site and the fact that since Camp Pendleton had internists and a cardiologist in the X Period, there was no room for improvement in service effectiveness as measured by ECG reader.

In order to achieve maximum benefit from the CAPOC system, changes are necessary at Camp Pendleton. Two additional three-channel transmitting

TABLE 3-5

SUMMARY OF QUANTITATIVE DATA FOR
CAMP PENDLETON NAVAL REGIONAL MEDICAL CENTER

	X Period	Y Period
Volume	12,000	12,000
Type		
Routine Outpatient	19%	19%
Annual Physical	15%	15%
Routine Inpatient	18%	48%
Pre-Operative	11%	11%
STAT/ER	3%	3%
Pediatric	4%	4%
Reader		
Cardiologist	11%	11.4%
Internist	89%	88.6%
Other	0	0
Interpretation		
Normal	47%	47%
Abnormal	53%	53%

TABLE 3-6

SUMMARY OF IMPACTS OF CAPOC ON EFFECTIVENESS OF ECG SERVICES
AT CAMP PENDLETON NAVAL REGIONAL MEDICAL CENTER

	Number of ECGs (Percent)		
	X Period	Y Period	Full Implementation
Reader			
Preferred	1,320 (11.0)	2,860 (23.8)	5,487 (45.7)
Acceptable	10,780 (89.0)	9,140 (76.2)	6,513 (54.3)
Turnaround Time			
Preferred	1,812 (15.1)	1,823 (15.2)	4,991 (41.6)
Acceptable	2,340 (19.5)	2,340 (19.5)	6,385 (53.2)
Abnormals with Serial Comparison	2,040 (32.1)	2,017 (31.8)	4,793 (75.5)
Conclusion			
Preferred	60 (0.5)	697 (5.8)	2,364 (19.7)
Acceptable	3,132 (26.1)	2,498 (20.8)	7,572 (63.1)
TOTAL	3,192 (26.6)	3,195 (26.6)	9,936 (82.8)

ECG carts must be secured for use in inpatient areas and the Emergency Room. Secondly, the automatic storage and retrieval of ECGs must be in operation. A change in the ECG process involving returning routine normal outpatient and pre-operative ECG tracings and CAPOC interpretations with the patient would increase the number of ECGs meeting criteria for effective turnaround time. These changes will result in an increase in ECG service effectiveness to 83 percent. The change will result from improved turnaround time and increased serial comparisons of abnormal ECGs. Preferred services will increase to 20 percent due to all physicians becoming preferred readers of computer-generated normal ECG interpretations.

5. Analysis of Qualitative Data

a. Physician Questionnaires

In the X Period, 46 physicians at Camp Pendleton returned staff questionnaires; in the Y Period, 40 physicians completed questionnaires.

Since transmission problems and lack of CAPOC ECG carts in primary care areas at Camp Pendleton led to a very low rate of ECG capture by CAPOC at the time the Y Period data were collected, the analysis of staff questionnaires from this site is focused on the perceptions of ECG readers (who are the only physicians with experience with CAPOC) of changes due to the system. No attempt is made to compare specific responses from the X and Y Periods regarding the performance of the manual and automated process in providing ECG services. Importance and satisfaction ratings in the X Period for various aspects of ECG services are discussed in order to identify areas in which to predict benefits of CAPOC when it is fully operational at this site.

i. ECG Functions

Ten of the 13 physician ECG readers during the Y Period had been at Camp Pendleton prior to the installation of CAPOC. They reported that their role in the ECG process had not changed as a result of CAPOC.

ii. Status of Implementation

Responses regarding ECG capture by CAPOC were predictable. Nine of the physician readers believed that ECGs were taken manually almost every day (the other four did not know). The most commonly cited reason was CAPOC not available in areas where ECGs were taken (nine responses), followed by CAPOC unavailable (four responses), manual system more satisfactory (three responses), and CAPOC not working (two responses).

iii. Service Response Times

Figures 3-12 and 3-13 display physician responses from the X Period regarding acceptable turnaround times for STAT ECGs. Figures 3-14 and 3-15 provide the same information for routine ECGs. These indicate that many of the physicians consider acceptable service response times to be similar to those used as evaluation criteria.

iv. Service Attributes

Figure 3-16 displays responses from the X Period regarding the importance of various aspects of ECG services and the physician's satisfaction with these aspects of the manual ECG process. In order to provide a basis for comparison, responses have been weighted as follows:

Importance Rating		Satisfaction Rating		Rating Value
Very important	1	Very satisfied	1	+2
	2		2	+1
	3		3	0
	4		4	-1
Very unimportant	5	Very dissatisfied	5	-2

The sums of all weighted responses to each question are displayed in Figure 3-16. The maximum possible cumulative rating for each attribute is 92 (46 physician responses time +2 rating value). The cumulative ratings concerning the importance of ECG service attributes are

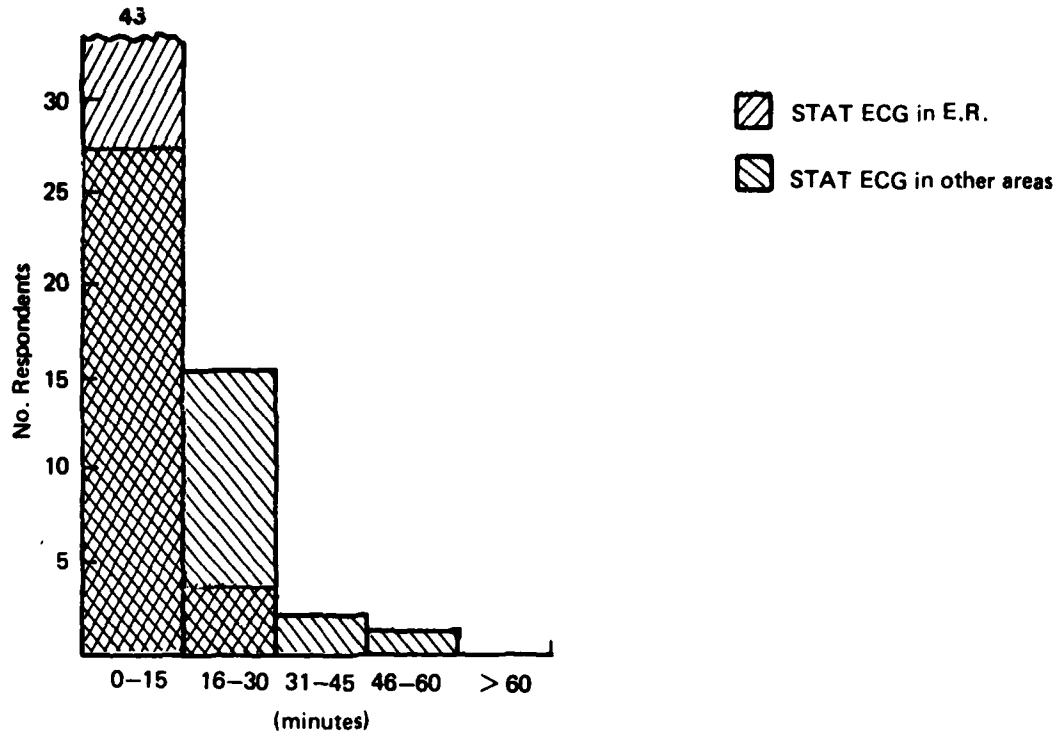

FIGURE 3–12 ACCEPTABLE DELAY BETWEEN REQUEST FOR STAT ECG AND TIME IT IS TAKEN–PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT CAMP PENDLETON NAVAL REGIONAL MEDICAL CENTER – X PERIOD

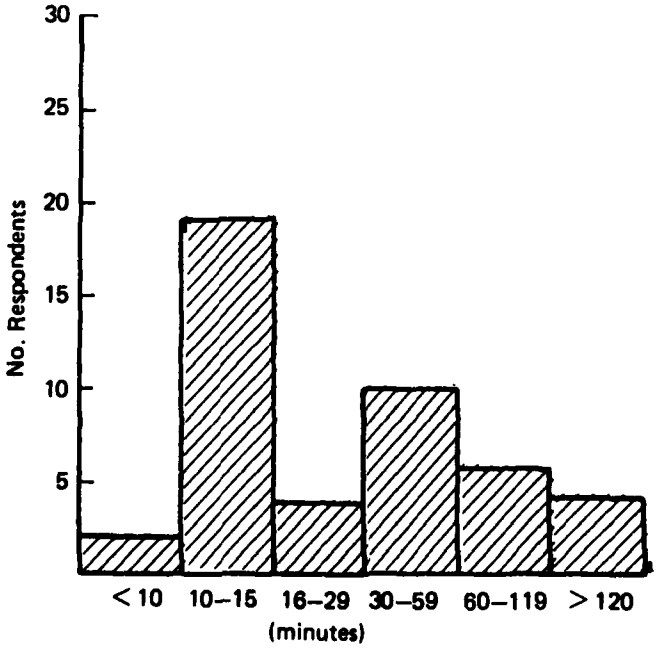

FIGURE 3–13 ACCEPTABLE DELAY BETWEEN REQUEST FOR STAT ECG AND AVAILABILITY OF INTERPRETATION–PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT CAMP PENDLETON NAVAL REGIONAL MEDICAL CENTER – X PERIOD

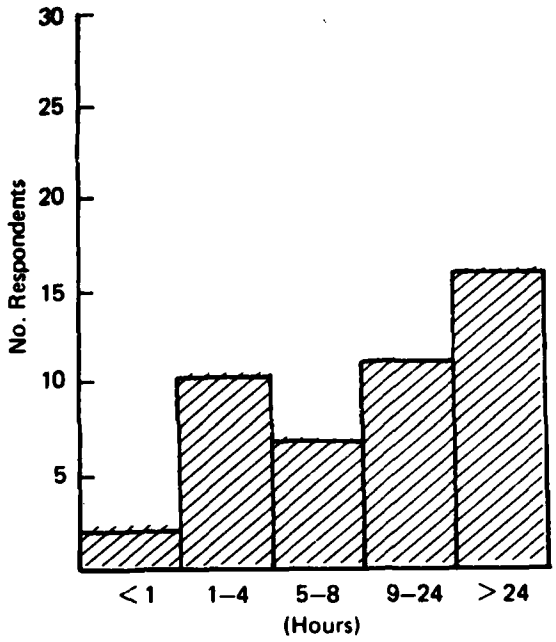

FIGURE 3–14 ACCEPTABLE DELAY BETWEEN REQUEST FOR ROUTINE ECG AND TIME IT IS TAKEN–PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT CAMP PENDLETON NAVAL REGIONAL MEDICAL CENTER – X PERIOD

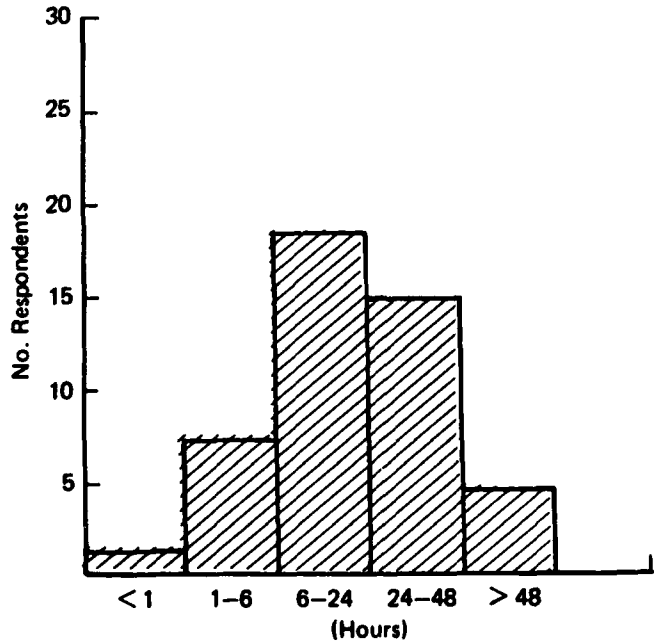

FIGURE 3–15 ACCEPTABLE DELAY BETWEEN REQUEST FOR ROUTINE ECG AND AVAILABILITY OF INTERPRETATION–PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT CAMP PENDLETON NAVAL REGIONAL MEDICAL CENTER – X PERIOD

shown on the left-hand side of Figure 3-16; those concerning satisfaction with the manual ECG system appear on the right-hand side.

As shown in Figure 3-16, all attributes regarding STAT ECGs received very high importance ratings. Physicians were considerably more satisfied with the current availability of tracings for STAT ECGs than with the availability of interpretations for STAT ECGs.

Service attributes regarding availability of tracings and interpretations for routine ECGs all received relatively low importance ratings. Physicians were generally dissatisfied with manual routine ECG services, in particular with the present turnaround time for interpretations.

Other service attributes rated as very important were accuracy and completeness of interpretations, use of serial comparison, and availability of experts to discuss the significance of ECG interpretations in patient management. Physicians were only marginally satisfied with these aspects of the manual ECG service; they expressed the most dissatisfaction with the availability of serial comparisons and availability of experts to discuss ECGs.

In response to questions in the Y Period regarding changes in ECG services resulting from CAPOC, at least 50 percent of the readers surveyed indicated no changes had occurred. This is not surprising, since the system was not operating very frequently because of technical problems. Mentions of improvements exceeded mentions of decreases for completeness and accuracy of interpretations and ease of reading and understanding ECG reports. More responses indicating a worsening of service were obtained regarding availability of tracings and interpretations for routine ECGs and the availability of prior ECG tracings for serial comparison.

However, many of the service attributes rated in the X Period as being very important to physicians at Camp Pendleton are likely to improve when the system is fully implemented. The experience at San Diego NRMC suggests that physicians will perceive improvements in interpretations (accuracy, consistency, ease of reading and understanding), and in the technical quality of tracings. If ECG carts with CAPOC capability are installed in the Emergency Room and the inpatient units, improvements in service response times and availability should also be achieved.

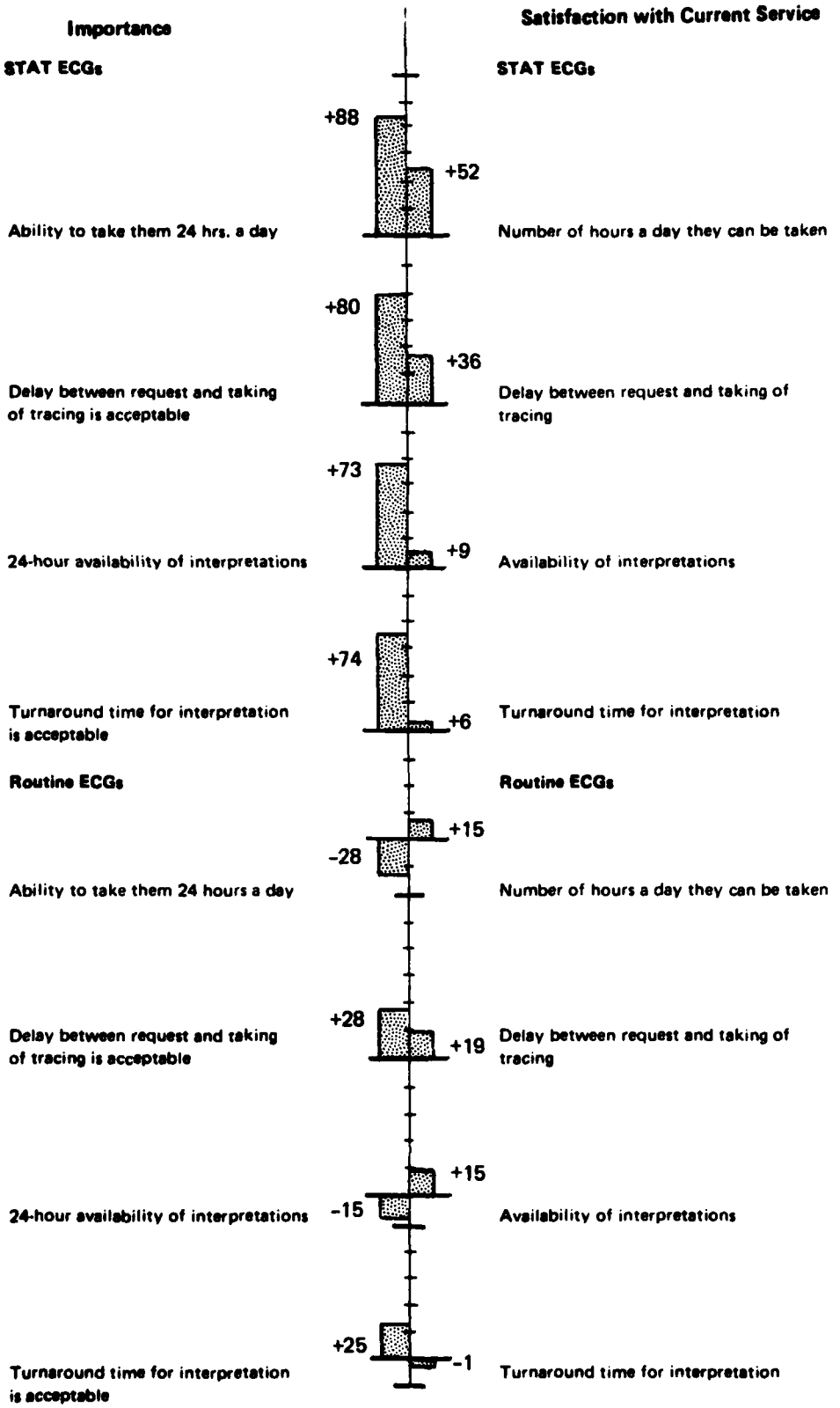

FIGURE 3–16 CUMULATIVE RATING OF ECG SERVICE ATTRIBUTES – PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT CAMP PENDLETON NAVAL REGIONAL MEDICAL CENTER – X PERIOD

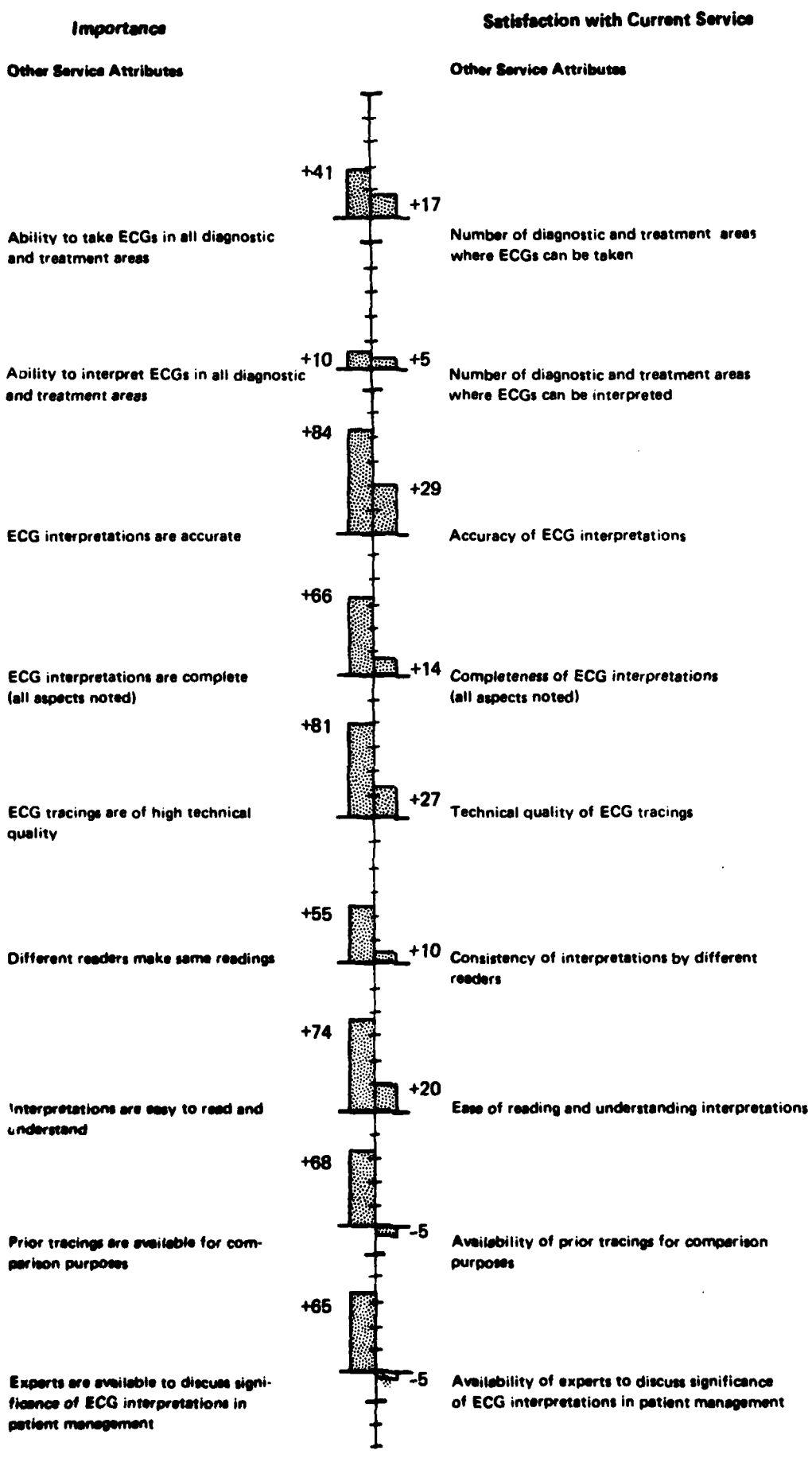

FIGURE 3–16 (Continued)

v. Accuracy

Responses from physician readers in the Y Period regarding the accuracy of CAPOC vs. manual ECG interpretation indicated that CAPOC was viewed as less reliable for abnormal ECGs, particularly myocardial infarctions, hypertrophy, and conduction abnormalities. For normal ECGs and other types of abnormal ECGs, no clear pattern emerged, since roughly equal numbers of physicians believed that CAPOC was more accurate, that manual reading was more accurate, or that there was no difference between the two modes. Four readers reported that computer errors tend to be false/negative results; one believed that false/positive results are more likely (five did not know).

vi. Reading Times

Responses from the X Period regarding time required to read ECGs are displayed in Figures 3-17 through 3-19.

In the Y Period, most readers reported no change in the time required to read/interpret ECGs. Again, comments were made to the effect that the system had not been fully implemented.

vii. Recalls/Referrals

Most physician readers reported that patient recalls due to poor quality tracings or lost ECGs were not changed by CAPOC as currently implemented. (Two respondents believed, however, that tracings were lost more frequently.) Generally, off-base referrals were also believed to be unchanged by the introduction of CAPOC.

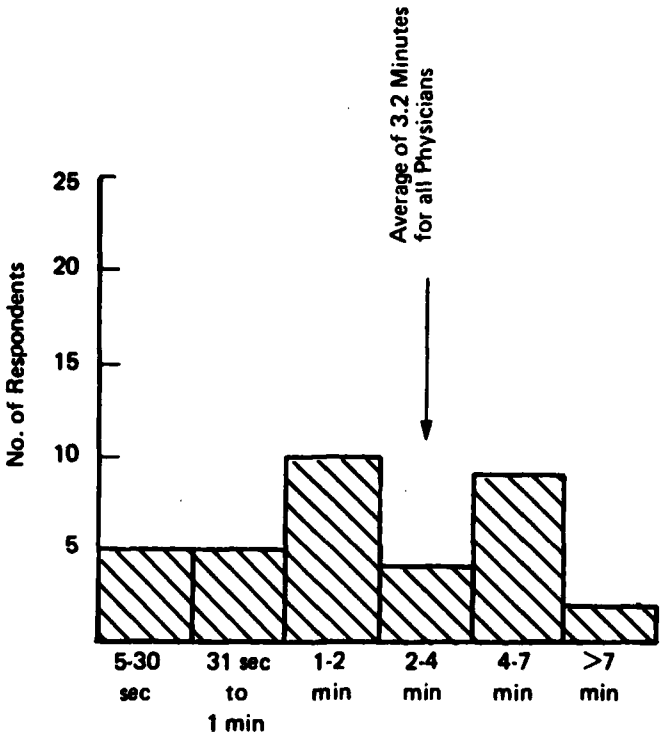

FIGURE 3–17 ESTIMATED TIME REQUIRED TO READ A NORMAL ECG – PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT CAMP PENDLETON NAVAL REGIONAL MEDICAL CENTER – X PERIOD

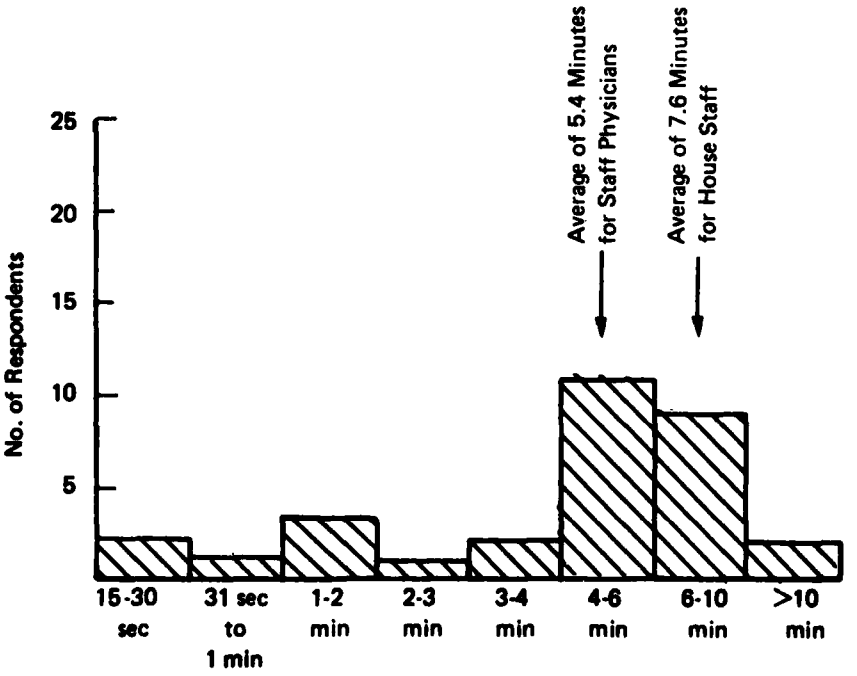

FIGURE 3–18 ESTIMATED TIME REQUIRED TO READ AN ABNORMAL ECG – PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT CAMP PENDLETON NAVAL REGIONAL MEDICAL CENTER – X PERIOD

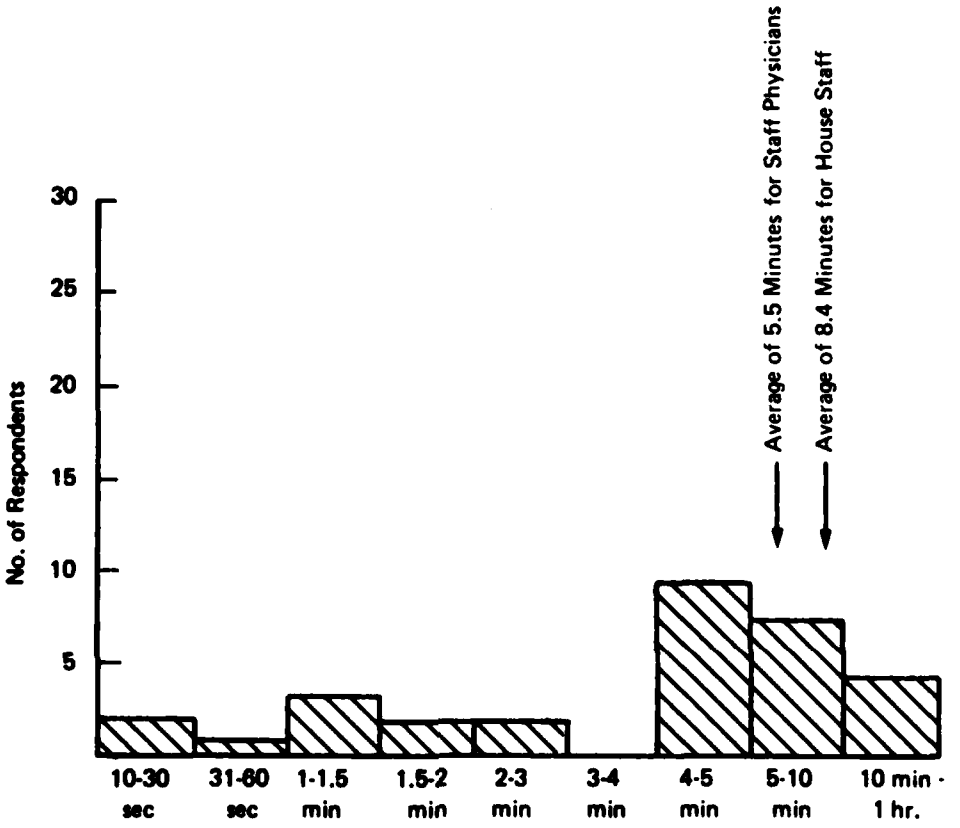

FIGURE 3–19 ESTIMATED TIME REQUIRED TO MAKE A SERIAL COMPARISON WITH A PRIOR ECG TRACING – PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT CAMP PENDLETON NAVAL REGIONAL MEDICAL CENTER – X PERIOD

viii. Other Comments

Physicians reported overall satisfaction with CAPOC as follows:

	Readers
Extremely satisfied	0
Very satisfied	1
Fairly satisfied	1
Somewhat unsatisfied	4
Very unsatisfied	2
Do not know	4

Recurring comments about ECG services included lack of access to routine ECGs, equipment allocation (especially the lack of CAPOC capability in the Emergency Room, and the lack of 12-lead machines in patient care areas) and malfunction.

6. Conclusions

At the time of the Y Period evaluation, only 30 percent of ECGs done at Camp Pendleton were being processed by CAPOC due to transmission problems and lack of carts in the inpatient wards and Emergency Room. Overall service effectiveness did not change from the baseline of 27 percent with CAPOC implementation; however, the preferred service level did increase to 6 percent from 1 percent in the X Period. When new carts are obtained, transmission problems solved, turnaround time improved, and automatic storage and retrieval are implemented, the service effectiveness will increase significantly to 83 percent. Physicians were generally dissatisfied with CAPOC services available in the fall of 1980 due to unresolved transmission problems and lack of equipment, which prevented the system from being used effectively.

C. USAF HOSPITAL, NELLIS AIR FORCE BASE

1. Introduction

The USAF Hospital at Nellis is the only Air Force facility included among the primary evaluation sites. Site visits to the secondary sites demonstrated that Nellis is quite typical of small Air Force hospitals, at least insofar as ECG services are concerned. Nellis, located on the outskirts of Las Vegas, Nevada, has a 40-bed hospital, which serves active-duty personnel from this base and their dependents and a growing population of retired military personnel. Inpatient admissions were 2,400 in the X Period and 2,600 in the Y Period. Outpatient visits to clinics declined from 200,000 in the X Period to 188,000 in the Y Period. The staff included 19 physicians, three of whom were internists, in both periods.

The hospital contains a two-bed Close Observation Unit, which is located on the ward across from the nursing station in order to facilitate visual monitoring of patients. For difficult diagnostic or treatment problems, patients are most often referred to nearby civilian hospitals.

2. ECG Service Organization and Staffing

At Nellis, ECGs were taken and processed in four locations: the Internal Medicine Clinic, the Flight Examination Clinic, the Emergency Room, and the wards. The ECG process at the time of the X Period data collection is described below. Changes that have resulted from CAPOC are also summarized.

In the Internal Medicine Clinic, most patients had a scheduled appointment for an ECG. Unscheduled ECGs were taken if time permitted. Patients arrived at the Clinic with a requisition. One of two Internal Medicine technicians took the ECG and recorded patient information in the Log Book. Then the tracing was left for mounting, which was usually done in the afternoon. (The mounting will be eliminated by CAPOC.)

An internist read the ECGs the next morning. Prior tracings were not usually retrieved for serial comparison. There was no three-channel transmitting cart in the Internal Medicine Clinic during the Y Period data collection. Thus, the ECG process had not changed and the ECGs were not impacted by CAPOC. There is a three-channel transmitting cart on order for Nellis, which will be installed in the Internal Medicine Clinic.

The Flight Examination Clinic took ECGs as part of annual flight examinations. Corpsmen assigned to the Clinic took the tracings. After all laboratory tests had been completed, the flight surgeon examined the patient, usually the same day. The ECG was often read during the examination. One of the flight surgeons was an internist and read most of these ECGs. The interpretation was stored in the patient's record in the Clinic. This record was always available to the flight surgeon for obtaining prior ECGs for serial comparison. A copy of the ECG was also forwarded to Brooke Air Force Base in Texas, where a central file of flight ECGs was kept. The ECG was also interpreted at Brooke and Nellis was contacted if follow-up examinations were recommended for the patient. All ECGs in the Flight Examination Clinic were being processed by CAPOC. The unconfirmed interpretation was attached to the ECG tracing to be seen by the examining physician.

ECGs taken in the Emergency Room were usually taken by corpsmen assigned to this service. They were read immediately by the General Medical Officer (who was most often a general practitioner, but sometimes was an internist since all physicians shared this duty). If the physician needed to consult another physician, an internist was usually available during the day, but had to be called to come in at night and on weekends. The patient's medical record was retrieved when possible. ECGs taken in the Emergency Room were processed by CAPOC. The unconfirmed interpretation was available for the physician.

On the inpatient wards, ECGs were usually taken by corpsmen and nurses assigned to these units. The patients included those in the Close Observation Unit, non-ambulatory patients, and those who needed tracings at night and on weekends. These ECGs were read by an internist

who was usually caring for most such patients on these wards. No inpatient ECGs were being processed by CAPOC during the Y Period data collection. The cart, which is on order, is expected to be used for these ECGs, in addition to the ones taken in the Internal Medicine Clinic.

In conclusion, only 54 percent of all ECGs taken at Nellis were being processed by CAPOC. When the new cart arrives, all ECGs are expected to be processed by CAPOC. Nellis receives only unconfirmed interpretations. There is no provision for overreading of these ECGs by a cardiologist at another site, such as San Diego NRMC.

3. Quantitative Data Collection Methodology

Several different methods were employed to collect X Period data at Nellis, including observation of the ECG process, review of existing records and log books, completion of data collection forms, and interviews with staff in all areas of the hospital where ECGs were taken. The data collection methods for the Y Period included interviews with pertinent staff (i.e., physicians and corpsmen), review of the ECG process, and review of ECG Log Books. The data obtained included ECG volumes by type of ECG, specialty of reading staff, turnaround times, and use of serial comparison.

4. Quantitative Data Analysis

a. Data on Volume and Type of ECG

The annual ECG volume in the X Period was 3,900. This number decreased by 12 percent to 3,147 in the Y Period. The medical staff attributed the decrease to a change in the criteria for ordering an ECG as part of an annual physical examination. The decrease might also be due to the 6 percent decrease in outpatient visits between the two periods.

b. Service Effectiveness Impact

Changes in the types of ECGs, the volumes read by different readers, and the category of interpretation are summarized in Table 3-7. Table 3-8 shows the levels of ECG service effectiveness at Nellis for the X and Y Periods and for full implementation of CAPOC. Service effectiveness increased from 41 percent in the X Period to 59 percent in the Y Period. There were two areas that contributed to the improvement: improved turnaround time and all physicians becoming preferred readers for normal ECGs with the back-up of the computer. When the new cart is available and all ECGs are captured by CAPOC, the level of service effectiveness is expected to be 84 percent. Since Nellis is not connected with a CAPOC overreading station, this site does not benefit from the ability to have abnormal ECGs read by a cardiologist off-site, or to have prior tracings automatically retrieved for serial comparison.

5. Analysis of Qualitative Data

In the X Period, staff questionnaires were returned by 11 physicians at USAF Hospital, Nellis Air Force Base. Ten physicians returned Y Period questionnaires; six of the respondents performed ECG reading functions. One CAPOC ECG cart is utilized in both the Flight Surgeon's Office, and the adjacent Emergency Room. Therefore, at the time of the Y Period data collection, ECG capture by CAPOC was limited for the most part to STAT ECGs in the Emergency Room and annual physical ECGs done in the Flight Surgeon's Office. Accordingly, the following analysis of questionnaire results has been focused on physician perceptions of CAPOC impacts on these aspects of ECG services. Furthermore, because of the small volume of ECGs processed at this site and the small number of physicians on the staff, qualitative and descriptive analysis was undertaken rather than data tabulations of the type done for San Diego NRMC.

In the Y Period, eight of the ten physician respondents at Nellis had been on the staff prior to the implementation of CAPOC. They reported that CAPOC had not altered their role in the ECG process.

TABLE 3-7

SUMMARY OF QUANTITATIVE DATA FOR
USAF HOSPITAL, NELLIS AIR FORCE BASE

	X Period	Y Period
Volume	3,900	3,417
Type		
Routine Outpatient	42%	36%
Annual Physical	26%	43%
Routine Inpatient	22%	8%
STAT/ER	10%	11%
Pediatric	0	2%
Reader		
Cardiologist	0	2.0%
Internist	90%	54.8%
Other	10%	43.2%
Interpretation		
Normal	67%	72.9%
Abnormal	33%	27.1%

TABLE 3-8

SUMMARY OF IMPACTS OF CAPOC ON EFFECTIVENESS OF ECG SERVICES
AT USAF HOSPITAL, NELLIS AIR FORCE BASE

	Number of ECGs (Percent)		
	X Period	Y Period	Full Implementation
Reader			
Preferred	0 (0)	1,616 (47.3)	2,518 (73.7)
Acceptable	3,510 (90.0)	1,540 (45.1)	638 (18.7)
Turnaround Time			
Preferred	1,404 (36.0)	1,845 (54.0)	1,982 (58.0)
Acceptable	1,034 (26.5)	718 (21.0)	1,401 (41.0)
Abnormals with Serial Comparison	117 (9.1)	179 (19.3)	585 (63.2)
Conclusion			
Preferred	0 (0)	1,548 (45.3)	1,630 (47.7)
Acceptable	1,595 (40.9)	468 (13.7)	1,240 (36.3)
TOTAL	1,595 (40.9)	2,016 (59.0)	2, 870 (84.0)

Regarding ECG capture by CAPOC, respondents indicated that manual ECGs were done almost every day (four responses) or at least once a week (three responses). Reasons given included CAPOC not working (six responses), CAPOC system too busy (four), CAPOC not available in all areas where ECGs were taken (three), and manual system more satisfactory (two). With regard to the last reason, one physician believed that longer ECG tracings (produced by the single-channel carts) were easier to read.

Figure 3-20 displays responses from the X Period survey concerning the relative importance of various attributes of ECG services and the degree of satisfaction with the ECG services provided in the manual mode. In order to provide a basis for comparison, responses have been weighted as follows:

Importance Rating		Satisfaction Rating		Rating Value
Very important	1	Very satisfied	1	+2
	2		2	+1
	3		3	0
	4		4	-1
Very unimportant	5	Very dissatisfied	5	-2

The sums of all weighted responses to each question are displayed in Figure 3-20. The maximum possible cumulative rating for each attribute is 22 (11 physician responses times +2 rating value). The cumulative ratings concerning the importance of ECG service attributes are shown on the left-hand side of Figure 3-20; those concerning satisfaction with the current ECG system appear on the right-hand side.

System attributes regarding STAT ECGs all were viewed as important, especially the 24-hour availability of tracings, which all 11 physicians rated as very important. Physicians were quite satisfied with the availability of tracings for STAT ECGs, but generally dissatisfied with the availability of interpretations under the current ECG service. Relative importance ratings for attributes of routine ECGs were low. Physicians at Nellis appeared to be only somewhat satisfied with current routine ECG services, but least satisfied with the availability of interpretations for routine ECGs.

Other system attributes rated as very important were accuracy of interpretations, high quality of ECG tracings, ease of reading and understanding interpretations, and availability of prior tracings for comparison purposes. Physicians were quite satisfied with the accuracy and completeness of interpretations provided by the manual ECG service and marginally satisfied with the number of diagnostic and treatment areas where ECGs could be taken and interpreted, the consistency and ease of reading and understanding interpretations, and the availability of serial comparisons. Their responses indicated that they were somewhat dissatisfied with the availability of experts to discuss the significance of ECG interpretations in patient management.

In response to a series of questions in the Y Period survey regarding CAPOC-induced changes in various aspects of ECG services, physicians confirmed the improvement in STAT ECG services (due to availability of CAPOC service in the Emergency Room at night); availability of and turnaround times for STAT ECG tracings and interpretations were reported to be improved by six respondents (the remainder indicated they did not know). Improvements were noted in accuracy (six vs. none) and completeness (five vs. none) of interpretations, ease of reading and understanding ECG reports (five vs. one), and quality of tracings (six vs. none).

Physicians were asked to compare the accuracy of CAPOC and manual ECG interpretations for normal and five types of abnormal ECGs. For every category, these physicians believe that manual reading was more accurate. They believed that computer errors tend to be false/positive results (six responses) rather than false/negative results (one response).

Figures 3-21 through 3-23 summarize responses from the X Period regarding time required to read ECGs. In the Y Period, most (six) physicians noted no change as a result of CAPOC; one each noted an increase or decrease of time devoted to these functions. The one who believed CAPOC required more time questioned the ability of CAPOC to identify abnormals. Those indicating no change noted the need to check computer results. Weekly ECG volumes for respondents from Nellis averaged 11 and 10 ECGs for the X and Y Periods, respectively.

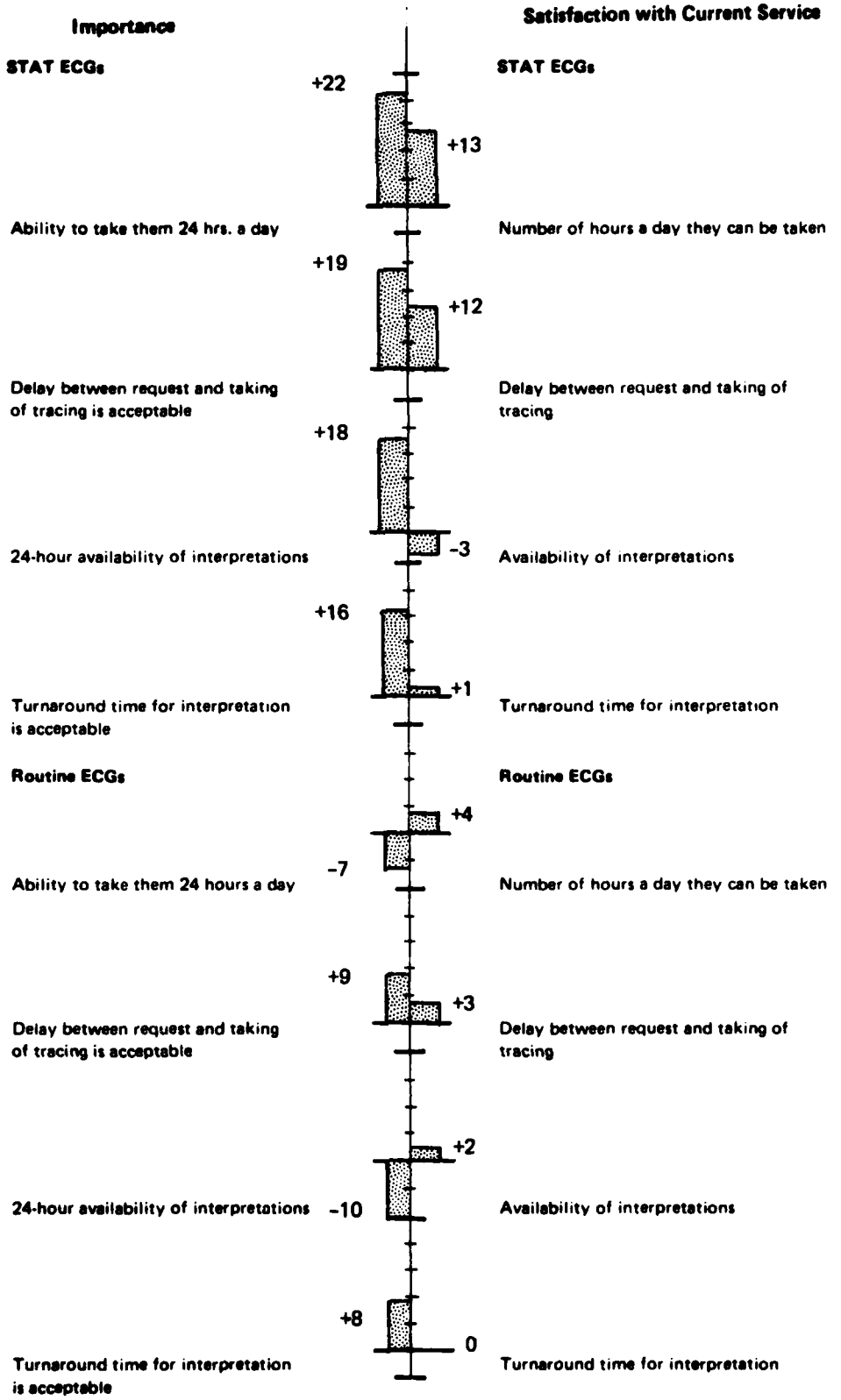

FIGURE 3–20 CUMULATIVE RATING OF ECG SERVICE ATTRIBUTES – PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT USAF HOSPITAL NELLIS AIR FORCE BASE – X PERIOD

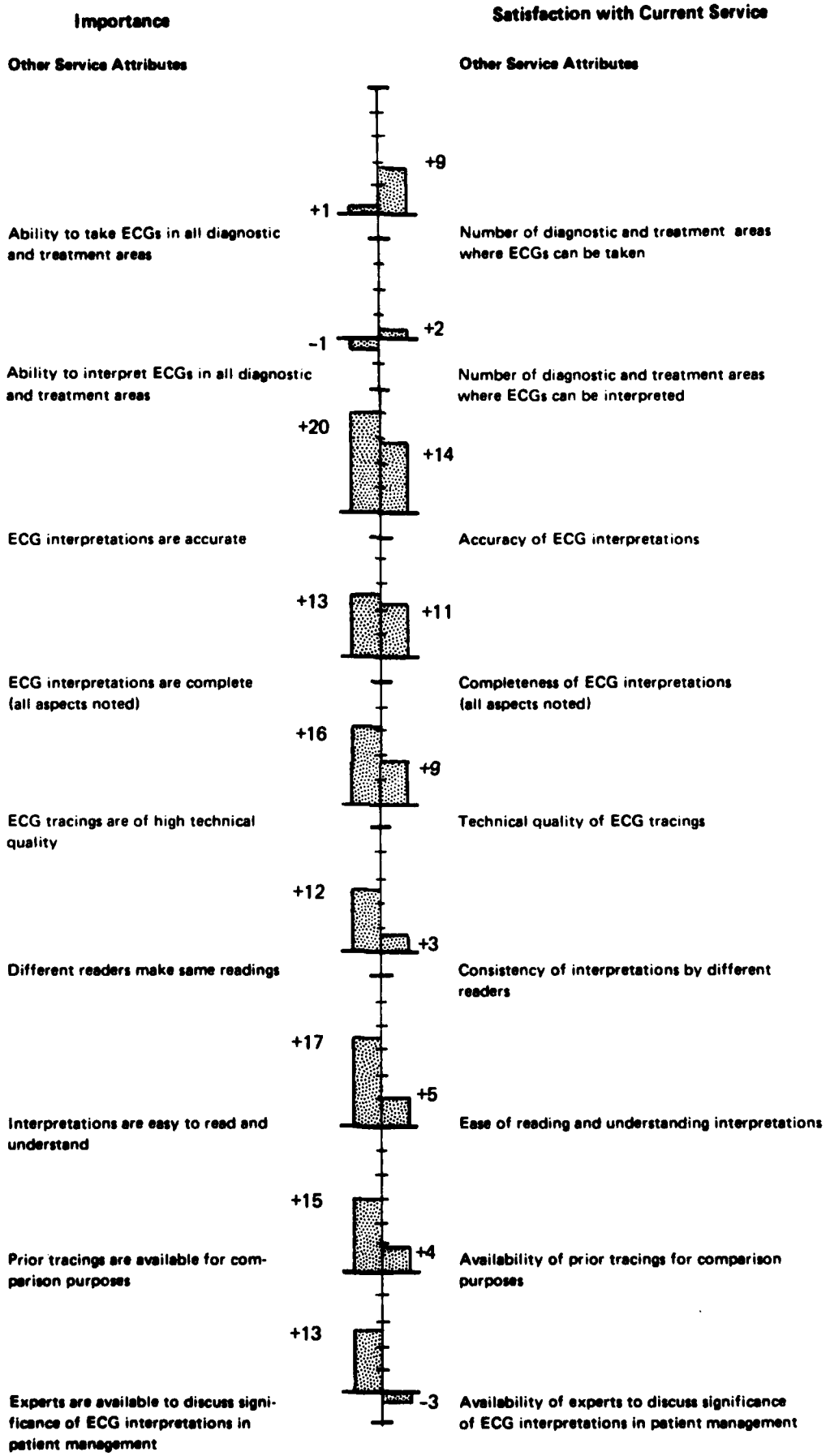

FIGURE 3–20 (continued)

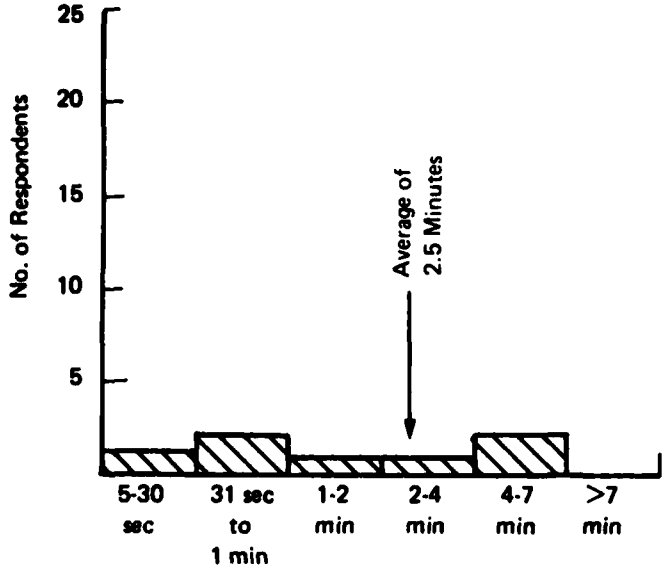

FIGURE 3–21 ESTIMATED TIME REQUIRED TO READ A NORMAL ECG – PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT USAF HOSPITAL, NELLIS AIR FORCE BASE – X PERIOD

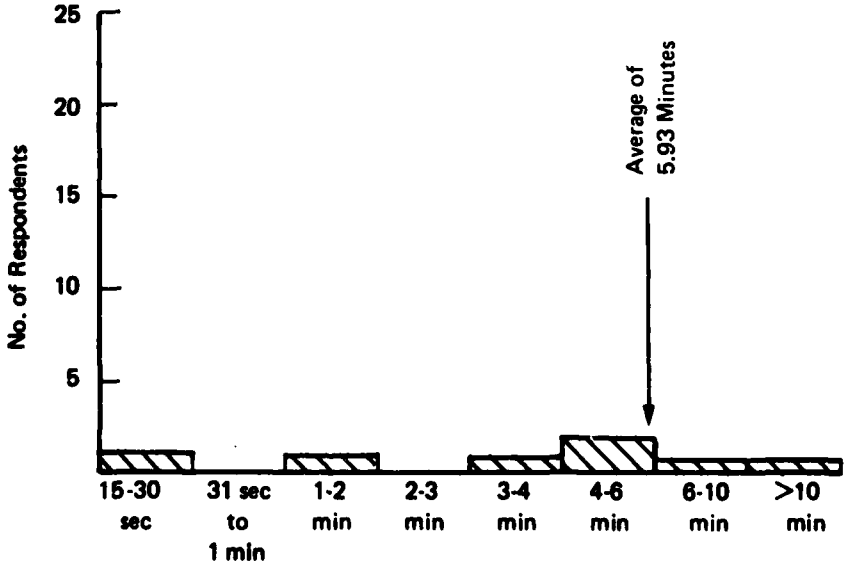

FIGURE 3–22 ESTIMATED TIME REQUIRED TO READ AN ABNORMAL ECG – PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT USAF HOSPITAL, NELLIS AIR FORCE BASE – X PERIOD

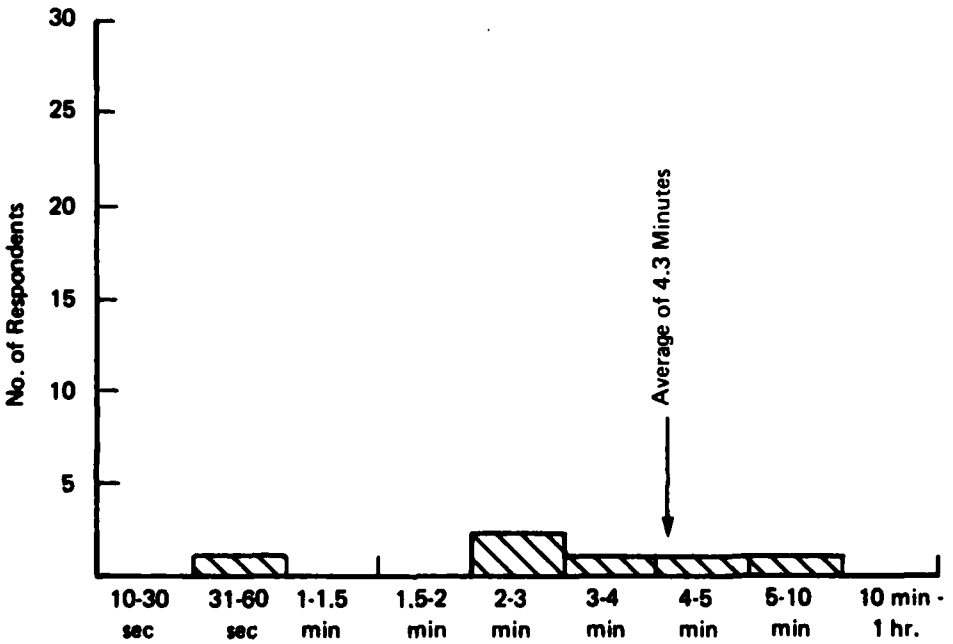

FIGURE 3–23 ESTIMATED TIME REQUIRED TO MAKE A SERIAL COMPARISON WITH A PRIOR ECG TRACING – PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT USAF HOSPITAL, NELLIS AIR FORCE BASE – X PERIOD

In the Y Period, physicians did not believe the number of off-base referrals had been changed by CAPOC. Two believed that patient recalls due to poor quality tracings had increased (one noted a decrease) and one respondent reported that recalls due to loss of ECGs had declined.

Physicians rated their overall satisfaction with CAPOC as follows:

Extremely satisfied	0
Very satisfied	3
Fairly satisfied	6
Somewhat unsatisfied	1
Very unsatisfied	0

Those who are generally satisfied noted quick reporting but some questioned the accuracy of interpretations. One respondent noted system downtime as a problem. Several comments indicated that interpretations for routine ECGs were not always received by the ordering physician.

6. Conclusions

The overall ECG service effectiveness at Nellis increased from 41 percent with manual services to 59 percent in the Y Period. This increase occurred despite only 54 percent of ECGs being processed by CAPOC due to a lack of a cart for certain areas. When the cart becomes available, the service effectiveness will increase to 84 percent. Physician staff commented on the rapid availability of an unconfirmed interpretation as a benefit of CAPOC.

D. TWENTYNINE PALMS MARINE CORPS BASE BRANCH HOSPITAL

1. Introduction

Twentynine Palms Branch Hospital is the smallest inpatient treatment facility included among the primary evaluation sites. Administratively, it is a component of the Command of Camp Pendleton Naval Regional Medical Center. However, for ECG services, Twentynine Palms operates quite autonomously from Camp Pendleton. The average monthly volume was 100 ECGs in 1979, the X Period.

Twentynine Palms is located in a remote desert area, approximately a 2-hour drive from the nearest referral hospital. When referrals are indicated, patients may be transported to either Camp Pendleton, San Diego, or a civilian hospital in Loma Linda, California.

The hospital had a maximum capacity of 34 beds with an average occupancy of 11 beds in 1979. Reportedly, occupancy varied from 0 to 34 beds. The hospital primarily served the 20,000 active-duty military personnel assigned to this Marine Corps Base, although this number increased substantially at times when major military maneuvers were held on base. The population of retired military personnel treated at Twentynine Palms was small, but had been increasing in recent years due to the proximity of the Palm Springs resort area.

The hospital staff in the X Period included 8 physicians: 6 in general medicine, 1 pediatrician, and 1 specialist in obstetrics and gynecology. CAPOC had not been implemented at Twentynine Palms during the Y Period data collection because of unresolved transmission problems.

2. ECG Service Organization Staffing

There was no structured ECG service, per se, at Twentynine Palms. Any corpsman caring for a patient--whether in the Emergency Room, Physical Examination Clinic or on the Military (Inpatient) Ward--might take an ECG when indicated. Three one-channel carts were available for taking ECGs in these locations. At the time of baseline data collection,

approximately 10 corpsmen took most of the ECGs, but reportedly any of the 100 staff could potentially take an ECG.

ECGs were read by the attending and ordering physician often immediately after they were taken, but always within one day. One physician, who had a particular interest in ECGs, served as overreader for the tracings when requested by the attending physician. The interpretation was usually written in the patient's chart or on the ECG itself, which was then inserted into the patient's chart. The chart was then available so that if a prior ECG was contained in the record, a serial comparison could be made.

Twentynine Palms is expected to have two three-channel transmitting ECG carts for use with CAPOC. One will be in the Family Practice Clinic adjacent to the Emergency Room and the other will be for use in the in-patient wards. The CAPOC printer will be located in the Family Practice Clinic.

3. Quantitative Data Collection Methodology

Quantitative data on ECG services at Twentynine Palms was difficult to obtain because of the low ECG volume. Therefore, data collection was designed specifically to capture the most relevant information for comparison with the ECG service criteria.

a. Data on Volumes and Types of ECG

Information on volumes was obtained by reviewing the ECG Log and the monthly report that is prepared for accounting purposes. Since these numbers differed from each other, interviews with staff were conducted in order to resolve conflicts. An estimate of actual volume and types of ECGs was made, based upon these interviews.

b. Turnaround Time

Data on turnaround time were obtained by asking the staff to complete a form specially designed for this purpose. These forms were attached

to the ECG after it was taken. The reader (and attending physician) was asked to fill in the time the ECG was interpreted and the time that the tracing and interpretation were returned to the patient's medical record. On this form, other information was requested concerning the type of ECG, the patient's age, and where the ECG was taken. A total of 16 forms were fully completed and four others were partially completed.

Other information on the staff reading, serial comparison, interpretation (normal or abnormal), and turnaround time was obtained through staff interviews. No data collection was done in the Y Period since the CAPOC system was not being used.

4. Quantitative Data Analysis

a. ECG Volumes

A review of the ECG Log for the months between September, 1978, and September, 1979, and the monthly morbidity reports prepared by the hospital for January, 1979 , through July, 1979, showed differences in reported volumes. The monthly volumes reported in the log ranged from 22-80 with an average of 55 ECGs per month. After interviews with staff, it was determined that the reported figures account for 60-70 percent of the volume that was actually done. On that basis, an estimate of 100 ECGs per month, or 1,200 per year, was developed for use in the evaluation.

The types of ECGs were determined from the 20 returned data collection forms. Interviews with staff were used to confirm whether the small sample obtained was representative of their typical ECG service. The percentages of total volume by type of ECG used for the evaluation are summarized in Table 3-9.

These volumes and types of ECGs are not expected to change significantly when CAPOC is implemented.

b. Service Effectiveness Impact

Data from the X Period concerning the type of ECG reader and the category of interpretation are summarized in Table 3-9; these data have been projected for full implementation of CAPOC at this site. These data are combined with data on acceptable and preferred turnaround times for different types of ECGs in Table 3-10, which summarizes the level of effective ECG services at Twentynine Palms during the X Period (and currently) and the projected impact of CAPOC implementation. No ECGs met effective service criteria in the X Period. It is projected that CAPOC implementation will raise the level of effective ECG services to 95 percent. This projection is based on the assumption that non-emergency abnormal ECGs will be overread by physicians at Camp Pendleton NRMC, and that the automatic storage and retrieval capability will be operational. The changes in service effectiveness will result from the physicians at Twentynine Palms becoming preferred readers for confirming computer-generated normal ECG interpretations, and the access to overreading of abnormal ECGs by physicians at Camp Pendleton NRMC.

5. Analysis of Qualitative Data

a. Questionnaire Administration

In the X Period, staff questionnaires were distributed by the CAPOC representative at Camp Pendleton to all eight physicians at Twentynine Palms and to approximately 50 percent of other staff likely to use ECGs. Questionnaires were returned by seven physicians, four nurses, and 27 corpsmen.

No questionnaires were distributed in the Y Period because CAPOC had not been implemented at that time. The following discussion focuses

TABLE 3-9

SUMMARY OF QUANTITATIVE DATA FOR
TWENTYNINE PALMS MARINE CORPS BASE BRANCH HOSPITAL

	X Period	Projected
Volume	1,200	1,200
Type		
Routine Outpatient	20%	20%
Annual Physical	70%	70%
Routine Inpatient	4%	4%
Pre-Operative	2%	2%
STAT/ER	4%	4%
Reader		
Cardiologist	0	2.1%
Internist	0	17.1%
Other	100%	80.8%
Interpretation		
Normal	80%	80%
Abnormal	20%	20%

TABLE 3-10

SUMMARY OF IMPACTS OF CAPOC ON EFFECTIVENESS OF ECG SERVICES
AT TWENTYNINE PALMS MARINE CORPS BASE BRANCH HOSPITAL

	Number of ECGs (Percent)		
	X Period	Y Period	Full Implementation
Reader			
Preferred	0 (0)	*	985 (82.1)
Acceptable	0 (0)		205 (17.1)
Turnaround Time			
Preferred	1,200 (100.0)	*	1,142 (95.2)
Acceptable	0 (0)		58 (4.8)
Abnormals with Serial Comparison	144 (60.0)	*	190 (79.2)
Conclusion			
Preferred	0 (0)	*	975 (81.3)
Acceptable	0 (0)		170 (14.1)
TOTAL	0 (0)	*	1,145 (95.4)

*Not implemented during Y Period data collection.

on the results of questionnaires distributed in the X Period and projections of the likely changes in satisfaction with services at Twentynine Palms when CAPOC is operational.

i. ECG Functions

All seven staff physicians at Twentynine Palms who completed questionnaires ordered ECGs to be taken on patients and interpreted ECGs for their own patients. Three also interpreted ECGs for patients treated by others. Four of the physician respondents had held their current position at Twentynine Palms for at least a year, three for less than six months. It should be noted that the seven physician respondents represented all but one of the physician staff at Twentynine Palms.

ii. Service Response Times

In order to establish what levels of ECG services physicians at Twentynine Palms considered acceptable, they were asked about response times to take an ECG tracing and turnaround times to receive an interpretation.

Figures 3-24 and 3-25 show the distribution of responses regarding the acceptable delays between an order for a STAT ECG and between the order for and receipt of an interpretation for a STAT ECG. For STAT ECGs in the Emergency Room, all seven physician respondents agreed that 15 minutes was the maximum acceptable delay before a tracing was taken. Though responses regarding the delay for STAT ECG tracings in other areas were more widely distributed, only two physicians indicated that a delay of more than 30 minutes was acceptable. Acceptable turnaround times for STAT ECGs, shown in Figure 3-25, indicate that only two physicians considered a turnaround time of more than 15 minutes acceptable.

The responses regarding service response times for routine ECGs are summarized in Figures 3-26 and 3-27. Five of the seven respondents indicated that the acceptable delay for obtaining the tracing was between 0 and 4 hours and the acceptable delay for return of the interpretations was 1-24 hours.

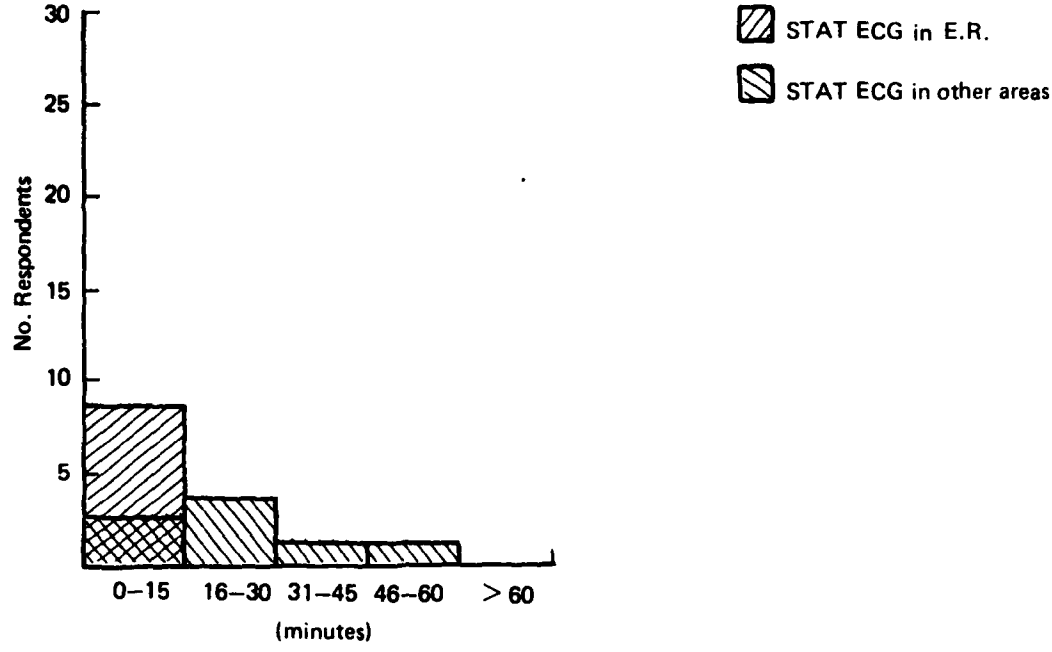

FIGURE 3–24 ACCEPTABLE DELAY BETWEEN REQUEST FOR STAT ECG AND TIME IT IS TAKEN–PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT TWENTYNINE PALMS MARINE CORPS BASE BRANCH HOSPITAL – X PERIOD

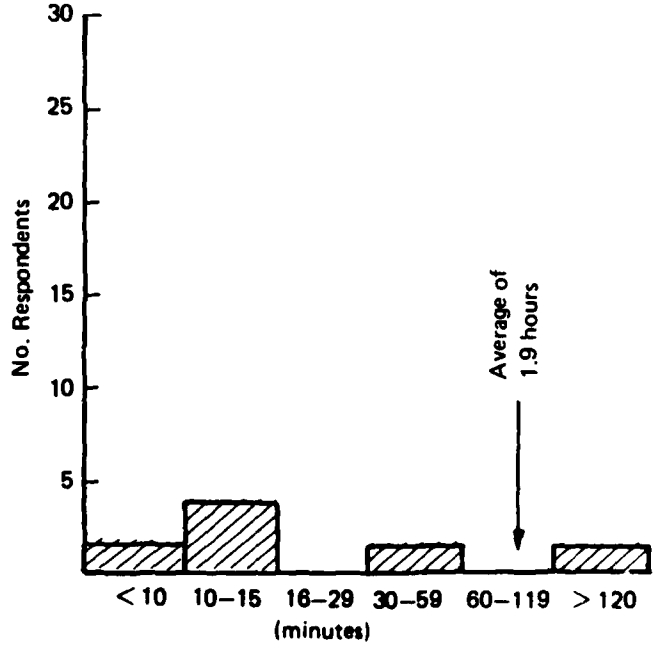

FIGURE 3–25 ACCEPTABLE DELAY BETWEEN REQUEST FOR STAT ECG AND AVAILABILITY OF INTERPRETATION–PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT TWENTYNINE PALMS MARINE CORPS BASE BRANCH HOSPITAL – X PERIOD

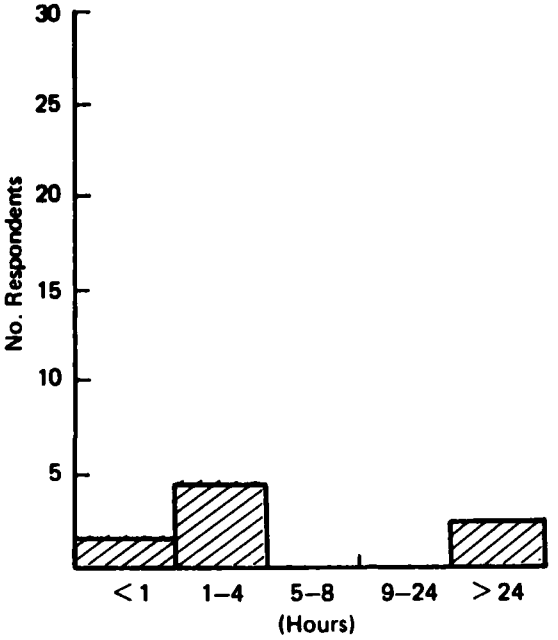

FIGURE 3–26 ACCEPTABLE DELAY BETWEEN REQUEST FOR ROUTINE ECG AND TIME IT IS TAKEN – PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT TWENTYNINE PALMS MARINE CORPS BASE BRANCH HOSPITAL – X PERIOD

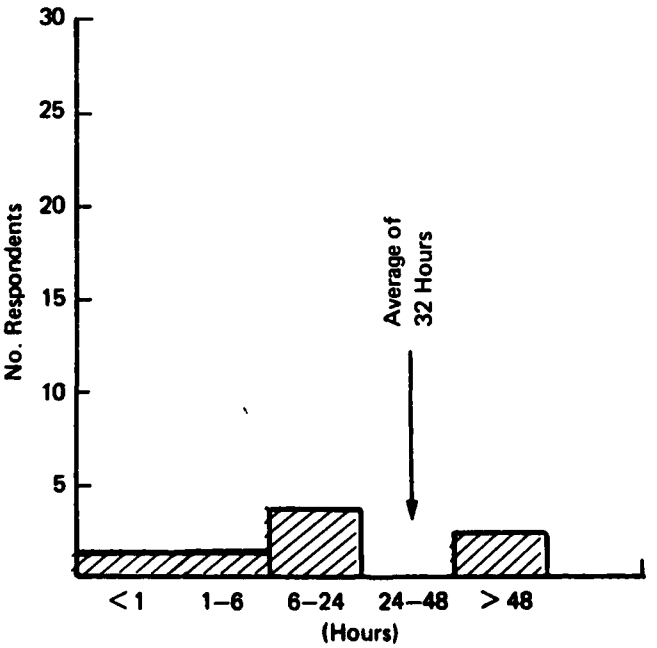

FIGURE 3–27 ACCEPTABLE DELAY BETWEEN REQUEST FOR ROUTINE ECG AND AVAILABILITY OF INTERPRETATION – PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT TWENTYNINE PALMS MARINE CORPS BASE BRANCH HOSPITAL – X PERIOD

iii. Attributes of ECG Services

Figure 3-28 summarizes the results derived from the portion of the staff questionnaire concerning the importance of certain attributes of ECG services and the degree of satisfaction with the performance of the current ECG system. In order to provide a basis for comparison, responses have been weighted as follows:

Importance Rating		Satisfaction Rating		Rating Value
Very important	1	Very satisfied	1	+2
	2		2	+1
	3		3	0
	4		4	-1
Very unimportant	5	Very dissatisfied	5	-2

The sums of all weighted responses to each question are displayed in Figure 3-28. The maximum possible cumulative rating for each attribute is 14 (7 physician responses times +2 rating value). The cumulative ratings concerning the importance of ECG service attributes are shown on the left-hand side of Figure 3-28; those concerning satisfaction with the current ECG system appear on the right-hand side.

All attributes of STAT ECG services were viewed as very important, as shown in Figure 3-28. The responses indicate that physicians were quite satisfied with the availability of ECG tracings from the current service, but only marginally satisfied with the availability of interpretations for STAT ECGs. The corresponding features of routine ECG services were rated as relatively unimportant, in particular 24-hour coverage for tracings and interpretations. Physicians were also fairly dissatisfied with the turnaround time for interpretations for routine ECGs, but quite satisfied with the ability of the current service to provide tracings.

Service attributes regarding accuracy, completeness, and ease of understanding interpretations were rated by all seven physician respondents as very important, as were the technical quality of the ECG tracing and

the availability of prior tracings for serial comparison. All of these aspects of the current service were reported to be only marginally satisfactory as shown in Figure 3-28. Physicians were quite dissatisfied with the availability of experts to discuss the significance of ECG interpretations in patient management.

iv. Recalls/Referrals

Patients sometimes have to be recalled for a repeat ECG tracing because the quality of the first tracing was poor, according to four physician respondents at Twentynine Palms. Repeats necessitated by loss of the ECG were not reported, but four physicians indicated that they did not know about this aspect of service. All seven indicated that patients are referred to other medical facilities, and three reported that these referrals are often necessary. The reasons cited were lack of a cardiologist and the need for specialized cardiology services or a second opinion.

v. Other Comments

Other physician comments regarding X Period ECG services at Twentynine Palms were solicited. Recurring comments concerned the lack of a staff cardiologist and the age of the ECG equipment at the site.

vi. Projected CAPOC Impacts

CAPOC should result in an improvement in the level of satisfaction with services in regards to relative importance of the attributes as displayed in the left column of Figure 3-28. Attributes where a large discrepancy was noted include:

- accuracy,
- completeness of interpretation,
- technical quality of tracing,
- ease of reading and interpretation,

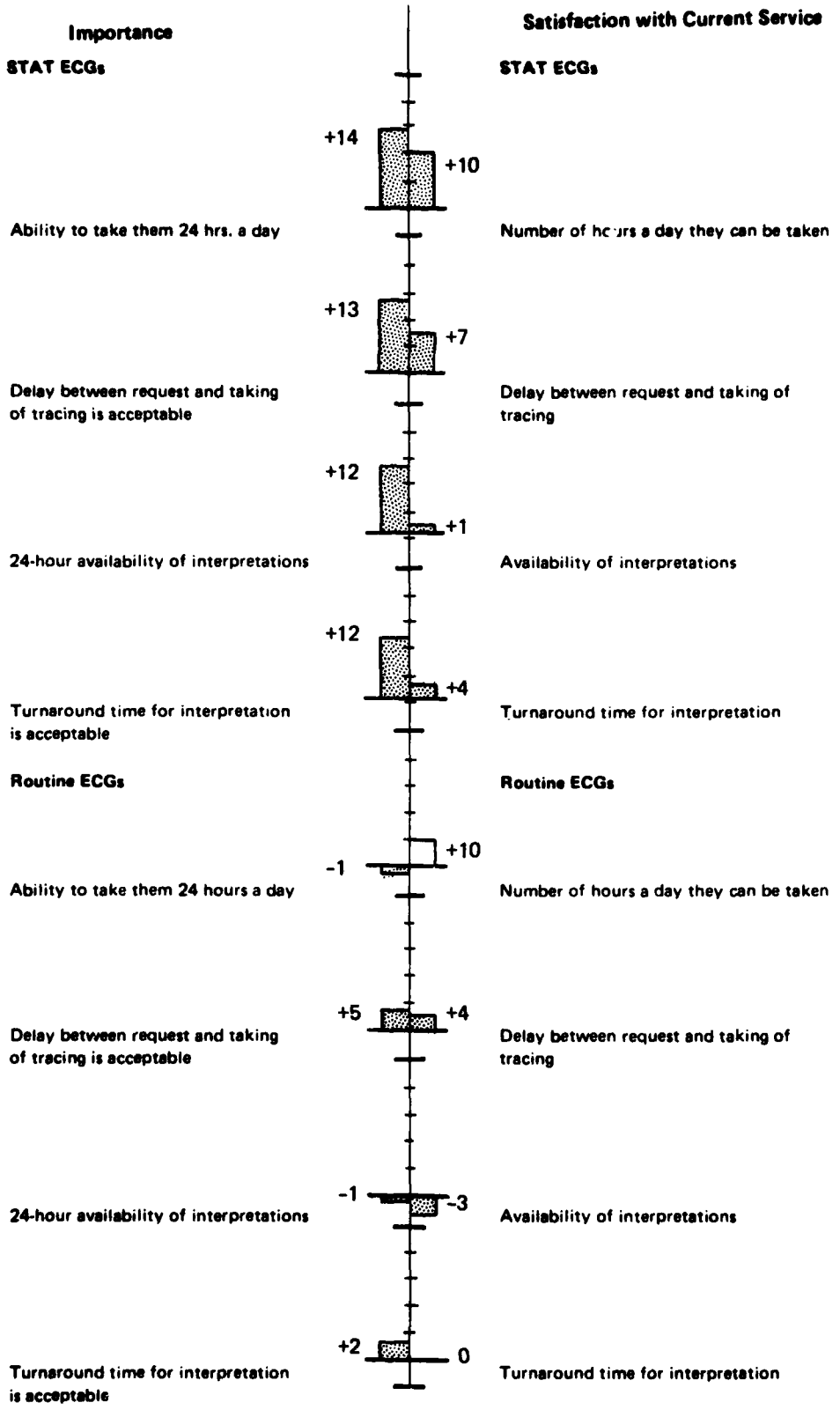

FIGURE 3–28 CUMULATIVE RATING OF ECG SERVICE ATTRIBUTES – PHYSICIAN RESPONDENTS TO STAFF QUESTIONNAIRE AT TWENTYNINE PALMS MARINE CORPS BASE BRANCH HOSPITAL – X PERIOD

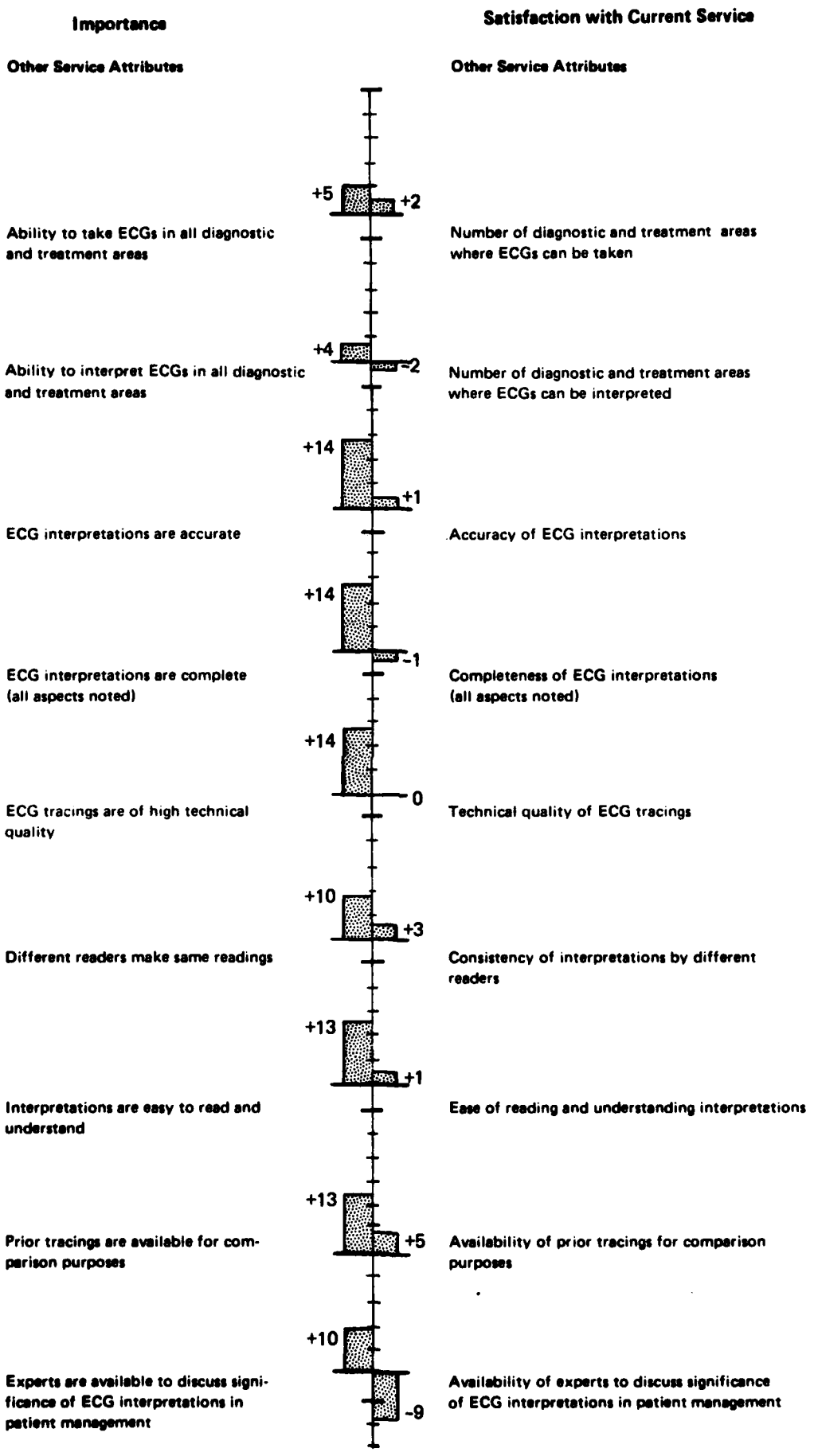

FIGURE 3–28 (continued)

- availability of experts to discuss significance of interpretation,
- availability, and
- turnaround time.

CAPOC will enhance completeness, technical quality, and availability. The availability of unconfirmed computer-generated interpretations should improve accuracy. The availability of experts to discuss significance of ECG interpretations in patient management should increase because physicians at Camp Pendleton NRMC or San Diego NRMC can obtain a copy of the ECG tracing immediately when called by a physician at Twentynine Palms. Previously, the physician would have sent the ECG or, possibly, the patient to one of these facilities for an evaluation.

6. Conclusions

CAPOC was not implemented at Twentynine Palms during the Y Period data collection. When CAPOC is implemented, the level of effective ECG services is expected to be improved significantly. The improvements will come primarily in the availability of effective readers at the site for normal ECGs and access to readers at Camp Pendleton NRMC for abnormal ECGs.

E. MIRAMAR NAVAL AIR STATION BRANCH CLINIC

1. Introduction

Miramar Branch Clinic is a small outpatient clinic, and the only primary evaluation site that lacks inpatient services. Administratively, Miramar is a component of the San Diego Naval Regional Medical Center, but it operates ECG services quite autonomously. It is located approximately 20 miles north of San Diego.

In 1979 (the X Period) outpatient visits to the clinic totalled 116,000. Of these 49 percent were by active-duty military, 42 percent were by dependents of active-duty personnel, and the remaining 9 percent were by retirees and their dependents.

In 1980 (the Y Period) there were 111,000 outpatient visits. The breakdown was 59 percent active-duty military, 34 percent dependents of active-duty personnel, and 7 percent retirees and their dependents. The primary patient population came from the Naval Air Station. However, due to the geographic proximity of the City of San Diego, patients from this area also used the clinic.

Miramar provides routine outpatient care, emergency services, and annual flight physicals. Patients requiring more specialized outpatient care or inpatient care are referred to San Diego NRMC.

There were 15 physicians on the clinic staff in both periods, six of these were general practitioners.

2. ECG Service Organization and Staffing

The process for obtaining ECGs did not change with the implementation of CAPOC. In both the X and Y evaluation periods, the majority of ECGs were taken in two locations--the Flight Examination Clinic and the Emergency Room. Some patients who were having flight examinations received an ECG as part of these examinations (depending upon the patient's age and date of previous ECG). If an ECG was indicated, a corpsman took the tracing and included it with the patient's record and other laboratory test results. These were reviewed and the ECG was interpreted when the flight surgeon examined the patient; the interpretation was written in the patient's record.

STAT ECGs were taken in the Emergency Room by corpsmen assigned to this unit. These were taken either in response to a physician's order, or to obvious or clinical symptoms, such as chest pain or irregular heart rate. STAT ECGs were interpreted by the attending physician and the interpretation was written in the patient's record.

Routine outpatient ECGs were taken in either location or the ECG cart was moved to another part of the Branch Clinic if indicated. These tracings were interpreted by the attending physician and the interpretation was written in the patient's record.

On rare occasions, a STAT ECG would be transported by automobile to San Diego NRMC for interpretation or the patient and ECG would be referred to San Diego by ambulance for a cardiology consult. For abnormal ECGs where there was no emergency and where a follow-up examination was indicated, patients were referred to the routine Cardiology Clinic held in San Diego.

After CAPOC was implemented, the corpsman attached the unconfirmed interpretation to the ECG tracing. Thus, the physician had the unconfirmed interpretation available when he saw the patient. Confirmed interpretations were returned the next morning following the reading and editing at San Diego NRMC.

In the X Period, Miramar had a single-channel ECG cart, purchased in 1972, and a three-channel transmitting cart, purchased in 1979 in anticipation of CAPOC. The single-channel cart was used as a back-up. A printer was added after CAPOC services were installed.

3. Quantitative Data Collection Methodology

Data collection at Miramar was limited due to the low volume of ECGs taken and the uncomplicated ECG services provided at this small Branch Clinic. In total, four separate site visits were made in the X Period by one or two team members. During these visits, information was collected on ECG types and volumes, ECG procedures, turnaround time, use of serial comparison, and reading staff procedures. The information was gained through a review of log books and reports and interviews with staff.

One site visit was made in the Y Period to ascertain the status of implementation, distribute staff questionnaires, interview personnel, and

collect quantitative data. In the Y Period, much of the quantitative data was available from the computer-generated workload reports.

4. Quantitative Data Analysis

a. ECG Volumes

The annual ECG volume for both periods was 1,320 (see Table 3-11). The estimate for the Y Period was based on an analysis and projection of three months of volume as reported by the CAPOC system. Transmission problems had prevented ECGs being processed by CAPOC until August, 1980. At the time of Y Period data collection, the problem with the cart still existed and some ECGs were still not being processed by CAPOC. This problem must be solved if full utilization is to be achieved.

b. Service Effectiveness Impact

Table 3-11 presents results for ECG reader and the numbers of normal and abnormal interpretations.

Table 3-12 presents the levels of ECG service effectiveness for the X and Y Period and for full implementation. No ECGs met effective service criteria during the X Period. In the Y Period, 70 percent of all ECGs met effective service criteria. The change was due to the general practitioner becoming a preferred reader of normal ECGs with the back-up of the computer-generated interpretation and access to specialists at San Diego NRMC for overreading of abnormal ECGs. When the automatic storage and retrieval of prior ECGs becomes operational and the intermittent problems with the cart are solved, the level of service effectiveness will increase to 93 percent.

5. Analysis of Qualitative Data

No physician questionnaires were available for the X Period. In the Y Period, seven physicians at Miramar returned completed staff questionnaires; four of the respondents performed ECG overreading functions at the site (these are referred to as "readers"). Most had been assigned to Miramar since May, 1980. Furthermore, at the time of Y Period data

TABLE 3-11

SUMMARY OF QUANTITATIVE DATA FOR
MIRAMAR NAVAL AIR STATION BRANCH CLINIC

	X Period	Y Period
Volume	1,320	1,320
Type		
Routine Outpatient	47%	47%
Annual Physical	50%	50%
STAT/ER	3%	3%
Reader		
Cardiologist	0	29.1%
Internist	0	0
Other	100%	70.9%
Interpretation		
Normal	99%	70%
Abnormal	1%	30%

TABLE 3-12

SUMMARY OF IMPACTS OF CAPOC ON EFFECTIVENESS OF ECG SERVICES
AT MIRAMAR NAVAL AIR STATION BRANCH CLINIC

	X Period	Y Period	Full Implementation
Reader			
Preferred	0 (0)	1,308 (99.1)	1,308 (99.1)
Acceptable	0 (0)	0 (0)	0 (0)
Turnaround Time			
Preferred	1,320 (100.0)	1,134 (85.9)	1,134 (85.9)
Acceptable	0 (0)	186 (14.1)	186 (14.1)
Abnormals with Serial Comparison	8 (60.0)	7 (1.8)	317 (80.0)
Conclusion			
Preferred	0 (0)	924 (70.0)	1,082 (82.0)
Acceptable	0 (0)	0 (0)	149 (11.3)
TOTAL	0 (0)	924 (70.0)	1,231 (93.3)

collection, CAPOC had been fully operational for only 2 months. Therefore, physicians had not yet had very much experience with CAPOC. The following analysis is focused on CAPOC impacts on aspects of service in which physicians had gained some experience and on the perceptions of the possible benefits of full implementation over an extended period. The technical problems experienced with transmission, which prevented CAPOC use for many months, were mentioned on almost all responses to the questionnaire.

Five of the respondents commented on the impact of CAPOC on the amount of time they spent each week reading/interpreting ECGs. Three of these (two of them readers) reported that CAPOC had saved time, citing the assistance of CAPOC in interpreting abnormal ECGs (one response) and general time saved in evaluating each ECG (one response). Two respondents reported no time savings (one of them was a reader); one of these physicians commented that each ECG still had to be read manually in order to verify the CAPOC interpretation.

Two readers commented on the accuracy of CAPOC vs. manual reading. They agreed that CAPOC was more accurate for rhythm and conduction abnormalities, but otherwise their responses were evenly divided. Four of the respondents reported that computer errors tended to be false/positive results; one believed that false/negative results were more likely.

Physicians rated their overall satisfaction with CAPOC as follows:

Extremely satisfied	0
Very satisfied	1
Fairly satisfied	4
Somewhat unsatisfied	1
Very unsatisfied	0
Do not know	1

Free-form comments indicated that most physicians believed CAPOC would be beneficial when the system reliability was improved. The availability of ECG interpretations 24 hours per day was cited as a major benefit of the system. In addition to the technical difficulties alluded to previously, two physicians believed that technicians required further training in the use of the CAPOC system.

6. Conclusions

CAPOC has greatly improved the ECG services at Miramar Branch Clinic. Technical problems still existed at the time of Y Period data collection and were impeding full utilization of the system and staff acceptance. When the system is fully implemented at this site, 93 percent of the ECGs will meet criteria for effective services.

CHAPTER 4. SERVICE EFFECTIVENESS--SECONDARY SITES

A. USAF HOSPITAL, VANDENBERG AIR FORCE BASE

The USAF Hospital at Vandenberg Air Force Base is a 40-bed hospital operating at 75 percent occupancy. It is located near the town of Lompoc, California, approximately 30 miles north of Santa Barbara. Vandenberg provides general medical and surgical care and has a seven-bed ICU. Patients with complex diagnostic or treatment problems are usually referred to San Diego NRMC, Letterman Army Base, or Santa Monica (a civilian hospital in Santa Barbara). Outpatient visits numbered approximately 150,000 annually in 1979. In the X Period, the staff included one civilian cardiologist, two internists, and 15 other physicians.

In the X Period, the ECG Laboratory was part of the Family Practice Department and was staffed by three technicians who shared one equivalent full-time position. Each technician spent one week at a time taking ECGs and administering treadmill examinations. During the other 2 weeks, the technicians held other assignments in the Family Practice Department. Approximately 80 percent of their time in the ECG Laboratory was spent directly on ECG responsibilities.

ECGs were taken by the ECG Laboratory staff between 0730 and 1630 on Monday through Friday. On nights and weekends, ECGs were taken in the ER, ICU, or on the inpatient wards by a corpsman assigned to those units. There were two single-channel carts: one in the ECG Laboratory and one on an inpatient ward. CAPOC had not been implemented at Vandenberg during the Y Period data collection due to transmission and ECG cart problems. CAPOC equipment will include a three-channel transmitting ECG cart and printer.

Table 4-1 summarizes the quantitative results for this site. The annual ECG volume during the X Period was 2,808. This volume is not expected to be impacted by CAPOC implementation. Table 4-2 summarizes the level of ECG service effectiveness in the X Period (and currently) and the projected impact of CAPOC implementation on these services. Effective ECGs accounted for 57 percent of all ECGs in the X Period. When CAPOC is implemented, this level will increase to 76.5 percent. The increase will occur because internists become preferred readers for confirming

TABLE 4-1

SUMMARY OF QUANTITATIVE DATA FOR
USAF HOSPITAL, VANDENBERG AIR FORCE BASE

	X Period	Projected
Volume	2,808	2,808
Type		
Routine Outpatient	44%	44%
Annual Physical	19%	19%
Routine Inpatient	14%	14%
Pre-Operative	12%	12%
STAT/ER	11%	11%
Reader		
Cardiologist	47%	46.9%
Internist	27%	27.0%
Other	26%	26.1%
Interpretation		
Normal	59%	59%
Abnormal	41%	41%

TABLE 4-2

SUMMARY OF IMPACTS OF CAPOC ON EFFECTIVENESS OF ECG SERVICES
AT USAF HOSPITAL, VANDENBERG AIR FORCE BASE

	Number of ECGs (Percent		
	X Period	Y Period	Full Implementation
Reader			
Preferred	1,320 (47.0)	*	2,231 (79.5)
Acceptable	758 (27.0)		421 (15.0)
Turnaround Time			
Preferred	1,179 (42.0)	*	1,168 (41.6)
Acceptable	1,460 (52.0)		1,467 (52.2)
Abnormals with Serial Comparison	702 (60.0)	*	692 (60.0)
Conclusion			
Preferred	225 (8.0)	*	837 (29.8)
Acceptable	1,376 (49.0)		1,311 (46.7)
TOTAL	1,601 (57.0)	*	2,148 (76.5)

*Not implemented during Y Period data collection.

normal ECG interpretations produced by the computer. The proportion of ECG services meeting criteria for preferred services will increase from 8 percent in the X Period to 30 percent for full implementation.

Conclusions: CAPOC was not operational at Vandenberg during the Y Period data collection. Effective ECG services are expected to increase when CAPOC is implemented.

B. USAF HOSPITAL, EDWARDS AIR FORCE BASE

Edwards Air Force Base has a 25-bed hospital operating at 80 percent occupancy. It is located near the town of Rosamond, California, and 35 miles from the closest referral hospital in Lancaster, California. Depending upon the need for and availability of services, patients from Edwards may be referred to major civilian and military hospitals in southern California.

This small hospital has an Acute Care Unit, which is used for close observation or for stabilizing critical patients prior to being transported to a referral hospital. There were 14 physicians on the hospital staff at Edwards Air Force Base in both the X and Y Periods. One of them was an internist.

The ECG process at Edwards has not changed as a result of CAPOC implementation. Approximately 20 technicians took ECGs in six locations. Edwards has six ECG machines. One three-channel cart located in the Treatment Room that was purchased in 1978 in anticipation of CAPOC was used for taking most ECGs; the other five carts were single-channel models located in an inpatient ward, the Emergency Room, the area in which annual physical examinations are given, and two clinics. There was a CAPOC printer in the Treatment Room. In the Treatment Room, most of the ECGs were taken between 0730 and 1630, Monday through Friday. On nights and weekends, ECGs were either taken in the Emergency Room or on an inpatient ward.

Table 4-3 presents data on ECG volumes, readers, and type of ECG interpretation. The annual ECG volume was 3,780 ECGs in both the X and Y Periods. In the Y Period, only 37 percent of all ECGs were being done by CAPOC. ECGs done as part of annual physicals were not being captured because there was no three-channel, transmitting cart in the flight surgeon's office.

Table 4-4 presents a summary of ECG service effectiveness for the X and Y Periods and for full implementation. One quarter of all baseline ECGs met criteria for effective ECG services. This increased to 28 percent in the Y Period. The slight increase was due to the general practitioners who read ECGs done in the Emergency Room becoming preferred

TABLE 4-3

SUMMARY OF QUANTITATIVE DATA FOR
USAF HOSPITAL, EDWARDS AIR FORCE BASE

	X Period	Y Period
Volume	3,780	3,780
Type		
Routine Outpatient	10%	10%
Annual Physical	63%	63%
Routine Inpatient	10%	10%
Pre-Operative	7%	7%
STAT/ER	10%	10%
Reader		
Cardiologist	0	0
Internist	32%	32%
Other	68%	68%
Interpretation		
Normal	77%	77%
Abnormal	23%	23%

TABLE 4-4

SUMMARY OF IMPACTS OF CAPOC ON EFFECTIVENESS OF ECG SERVICES
AT USAF HOSPITAL, EDWARDS AIR FORCE BASE

	Number of ECGs (Percent		
	X Period	Y Period	Full Implementation
Reader			
Preferred	0 (0)	1,005 (26.6)	2,911 (77.0)
Acceptable	1,210 (32.0)	318 (8.4)	318 (8.4)
Turnaround Time			
Preferred	2,835 (75.0)	3,213 (85.0)	3,213 (85.0)
Acceptable	945 (25.0)	567 (15.0)	567 (15.0)
Abnormals with Serial Comparison	340 (39.1)	326 (37.5)	326 (37.5)
Conclusion			
Preferred	0 (0)	578 (15.3)	2,483 (65.7)
Acceptable	945 (25.0)	476 (12.6)	476 (12.6)
TOTAL	945 (25.0)	1,054 (27.9)	2,959 (78.3)

readers when confirming normal ECG interpretations generated by the computer. If the 63 percent of ECGs done in the flight surgeon's office were processed by CAPOC, the level of effective service would increase to 78 percent. This change would require that one additional three-channel ECG cart and printer be purchased for the flight surgeon's office.

Physicians at Edwards like the rapid availability of an unconfirmed interpretation, especially on nights and weekends. Due to the high turnover rate of corpsmen and the large number who take ECGs, insufficient training on CAPOC use was cited as a problem.

Conclusions: At Edwards Air Force Base Hospital, effective ECG services increased only slightly in the Y Period because the majority of ECGs were still being done in a manual mode. The automated system will have a significant impact on services when ECGs done as part of annual physicals are processed by CAPOC.

C. USAF HOSPITAL, GEORGE AIR FORCE BASE

George Air Force Base, located near Victorville, California, approximately 50 miles north of San Bernardino, has a small 42-bed hospital. The closest and most frequently used referral hospital is at March Air Force Base. Patients are occasionally transported to other large hospitals in southern California.

The hospital has a two-bed Close Observation Room for observing and monitoring critically ill patients. In both the X and Y Periods, the hospital staff included 15 physicians, two of whom were internists.

The ECG process did not change as a result of CAPOC implementation. There were two corpsmen/technicians who took most of the ECGs in the Treatment Room, which was part of the Primary Care service, one technician in the Flight Examination Department, and approximately 10 other corpsmen who took some ECGs on the wards and in the Emergency Room. ECGs were taken from 0730 to 1630 on Monday through Friday before and after automation. Most ECGs were taken in the morning. ECG technicians were assigned other duties when not taking ECGs.

In the X Period, there were four single-channel ECG carts at George. George acquired a three-channel transmitting ECG cart and printer for CAPOC. The printer was located in the Treatment Room.

Basic data on volume and type of ECGs and ECG readers are presented in Table 4-5. The annual ECG volume in the X Period was 1,332 ECGs. This volume had increased by 14 percent to 1,496 ECGs in the Y Period. Not all ECGs were being processed by CAPOC at the time of the Y Period site visit. Part of the ECGs done in the inpatient wards and during annual physicals were still being processed with a manual system. There were no telephone jacks in some areas of the inpatient wards, making CAPOC access impossible. ECGs done as part of annual physicals were not done by CAPOC for administrative reasons; this is expected to be changed soon so that all these ECGs can be done by CAPOC.

Table 4-6 summarizes the levels of ECG service effectiveness in the X and Y Periods and for full implementation. The overall level of ECG service effectiveness did not change with the implementation of CAPOC, nor is it projected to change when all ECGs are done by CAPOC

TABLE 4-5

SUMMARY OF QUANTITATIVE DATA FOR
USAF HOSPITAL, GEORGE AIR FORCE BASE

	X Period	Y Period
Volume	1,332	1,496
Type		
Routine Outpatient	37%	41%
Annual Physical	58%	52%
STAT/ER	3%	5%
Pediatric	2%	7%
Reader		
Cardiologist	0	0
Internist	0	0
Other	100%	100%
Interpretation		
Normal	64%	64%
Abnormal	36%	36%

TABLE 4-6

SUMMARY OF IMPACTS OF CAPOC ON EFFECTIVENESS OF ECG SERVICES
AT USAF HOSPITAL, GEORGE AIR FORCE BASE

	Number of ECGs (Percent)		
	X Period	Y Period	Full Implementation
Reader			
Preferred	0 (0)	537 (35.9)	748 (50.0)
Acceptable	1,332 (100.0)	959 (64.1)	748 (50.0)
Turnaround Time			
Preferred	493 (37.0)	554 (37.0)	554 (37.0)
Acceptable	539 (40.5)	606 (40.5)	607 (40.5)
Abnormals with Serial Comparison	400 (60.0)	449 (60.0)	449 (60.0)
Conclusion			
Preferred	0 (0)	173 (11.6)	317 (21.2)
Acceptable	839 (63.0)	767 (51.3)	624 (41.7)
TOTAL	839 (63.0)	940 (62.9)	941 (62.9)

upon full implementation. However, the level of preferred service will change due to CAPOC implementation. In the X Period, no ECGs met preferred service criteria. In the Y Period, 12 percent met preferred criteria, and it is projected that 21 percent will meet preferred criteria upon full implementation. This change is due to all readers becoming preferred readers for confirming the computer-generated interpretation of normal ECGs.

The physicians at George like the CAPOC system, especially the rapid availability of an unconfirmed interpretation. They also believe the quality of tracings has improved, partly due to CAPOC and partly due to the use of three-channel ECG machines.

Conclusions: CAPOC has not, and is not, expected to increase overall ECG service effectiveness at George. CAPOC has impacted the level of preferred services, and is perceived as having additional, unquantified benefits.

D. USAF MEDICAL FACILITY, NORTON AIR FORCE BASE

The USAF Medical Facility at Norton Air Force Base is a small outpatient clinic located in urban San Bernardino, California. For inpatient care, patients are referred to either March Air Force Base or to local civilian hospitals. In both the X and Y Periods, the hospital staff included 13 physicians, most of whom were either General Practitioners or Flight Surgeons.

The ECG process at Norton has not changed due to CAPOC implementation. ECGs were done primarily by one technician who also had other responsibilities. Four other technicians also knew how to take ECGs. Nearly all of the ECGs were taken in the ECG Laboratory, which operated from 0800 to 1630, Monday through Friday. A small percentage of the ECGs were taken in the Emergency Room. The clinic, including the Emergency Room, was closed on nights and weekends. Emergency services, including ECGs, were obtained at the referral hospitals.

In the X Period, there was one three-channel non-transmitting cart in the ECG Laboratory and a single-channel ECG cart in the ER. Norton acquired a three-channel, transmitting ECG cart and printer for use with CAPOC. Both pieces of equipment were placed in the ECG Laboratory. The non-transmitting cart was kept for back-up.

Basic quantitative results are summarized in Table 4-7. The annual ECG volume in the X Period was 2,880 (as estimated from log books maintained in the ECG Laboratory). This volume decreased to 2,426 in the Y Period. Only 63 percent of all ECGs done at Norton were being processed by CAPOC at the time of Y Period data collection. There were still intermittent problems with the telephone lines, such as being unable to get through and being disconnected in the middle of a transmission.

Table 4-8 presents a summary of the levels of effective ECG services in the X and Y Periods and projections of effectiveness when CAPOC is fully implemented. No ECGs met effective service criteria in the X Period because there were no cardiologists or internists at Norton. With CAPOC, any reader is considered a preferred reader for confirming normal ECG interpretations generated by the computer. This change resulted in 40 percent of all ECGs meeting effective service criteria in the Y Period.

TABLE 4-7

SUMMARY OF QUANTITATIVE DATA FOR
USAF HOSPITAL, NORTON AIR FORCE BASE

	X Period	Y Period
Volume	2,280	2,426
Type		
Routine Outpatient	18%	18%
Annual Physical	32%	32%
Routine Inpatient	45%	45%
STAT/ER	5%	5%
Reader		
Cardiologist	0	0
Internist	100%	77.6%
Other	0	22.4%
Interpretation		
Normal	50%	50%
Abnormal	50%	50%

TABLE 4-8

SUMMARY OF IMPACTS OF CAPOC ON EFFECTIVENESS OF ECG SERVICES
AT USAF MEDICAL FACILITY, NORTON AIR FORCE BASE

	Number of ECGs (Percent)		
	X Period	Y Period	Full Implementation
Reader			
Preferred	0 (0)	977 (40.3)	1,550 (63.9)
Acceptable	0 (0)	0 (0)	0 (0)
Turnaround Time			
Preferred	1,322 (58.0)	1,383 (57.0)	1,383 (57.0)
Acceptable	844 (37.0)	995 (41.0)	995 (41.0)
Abnormals with Serial Comparison	251 (30.5)	263 (30.0)	263 (30.0)
Conclusion			
Preferred	0 (0)	522 (21.5)	830 (34.2)
Acceptable	0 (0)	439 (18.1)	696 (28.7)
TOTAL	0 (0)	961 (39.6)	1,526 (62.9)

This level will increase to 63 percent when all ECGs are done by CAPOC. This increase at full implementation will be a result of capturing the additional 37 percent of ECGs taken at Norton.

Physicians at Norton report that they do not like the CAPOC system. They report a very low level of agreement between the unconfirmed report and their own interpretation. They feel that the disagreement can, in part, be explained by the technical problems in interfacing their transmitting cart, communication lines, and the CAPOC system.

Conclusions: Despite only 63 percent of all ECGs being done by CAPOC in the Y Period, CAPOC has had a major impact on the number of ECGs meeting evaluation criteria at Norton. This effect will be even greater when all ECGs are done by CAPOC. Technical difficulties may have resulted in dissatisfaction with the system. This issue needs further investigation and resolution.

E. USAF REGIONAL HOSPITAL, MARCH AIR FORCE BASE

The USAF Regional Hospital at March Air Force Base (March) is a medium-sized, 125-bed hospital located in Riverside, California. In addition to providing a broad range of health care services to its local patient population, this hospital serves as a referral hospital for other small military hospitals and clinics in the region. Patients with problems that cannot be handled at March are referred to San Diego NRMC or Loma Linda University Medical Center.

For delivery of acute cardiology care, March has a 10-bed combined cardiac care unit and intensive care unit. Pediatric cardiology care is provided by a cardiologist from San Diego NRMC who visits March once each month. In the X Period, there were five internists who shared ECG reading responsibilities. This number decreased to four in the Y Period. One internist was scheduled to read routine ECGs and one was assigned STAT ECGs each day in both periods.

The ECG process and technician staffing did not change between the X and Y Periods. Four technicians who did most of the ECGs were located in the Cardiopulmonary (CP) Laboratory. They each had other responsibilities in addition to those related to ECGs. The CP Laboratory staff took ECGs from 0730 to 1630, Monday through Friday. At night and on weekends, ECGs were taken in the Emergency Room, CCU, and inpatient wards.

In the X Period, the ECG equipment consisted of one three-channel, non-transmitting ECG cart located in the CP Laboratory and seven single-channel ECG carts located in the CP Laboratory, Emergency Room, inpatient wards, and CCU. In the Y Period, March acquired a three-channel transmitting ECG cart and printer for CAPOC while retaining all equipment in place previously. The CAPOC equipment was placed in the CP Laboratory. The three-channel non-transmitting cart was devoted to stress testing.

Table 4-9 presents data on volumes and types of ECGs and on ECG reader. The annual ECG volume in both X and Y Periods was estimated to be 6,000 ECGs. Only routine outpatient, pre-operative and Emergency Room ECGs were done by CAPOC during Y Period data collection because only one transmitting cart in the CP Laboratory was available. (This cart was also available for use in the Emergency Room.)

TABLE 4-9

SUMMARY OF QUANTITATIVE DATA FOR
USAF REGIONAL HOSPITAL, MARCH AIR FORCE BASE

	X Period	Y Period
Volume	6,000	6,000
Type		
Routine Outpatient	40%	40%
Annual Physical	21%	21%
Routine Inpatient	16%	16%
Pre-Operative	14%	14%
STAT/ER	8%	8%
Pediatric	1%	1%
Reader		
Cardiologist	0	0
Internist	100%	100%
Other	0	0
Interpretation		
Normal	72.5%	72%
Abnormal	27.5%	28%

TABLE 4-10

SUMMARY OF IMPACTS OF CAPOC ON EFFECTIVENESS OF ECG SERVICES
AT USAF REGIONAL HOSPITAL, MARCH AIR FORCE BASE

	Number of ECGs (Percent)		
	X Period	Y Period	Full Implementation
Reader			
Preferred	0 (0)	2,580 (43.0)	4,290 (71.5)
Acceptable	6,000 (100.0)	3,420 (57.0)	1,710 (28.5)
Turnaround Time			
Preferred	2,580 (43.0)	2,580 (43.0)	2,580 (43.0)
Acceptable	3,060 (51.0)	3,083 (51.4)	3,083 (51.4)
Abnormals with Serial Comparison	900 (54.5)	1,008 (60.0)	1,008 (60.0)
Conclusion			
Preferred	0 (0)	420 (7.0)	1,842 (30.7)
Acceptable	4,980 (83.0)	4,626 (77.1)	3,204 (53.4)
TOTAL	4,980 (83.0)	5,046 (84.1)	5,046 (84.1)

Table 4-10 summarizes the effectiveness of ECG services in the X and Y Periods and for full implementation. In the X Period, 83 percent of all ECGs met effective service criteria. This changed slightly to 84 percent in the Y Period. The lack of significant change is attributed to the fact that only 62 percent of all ECGs were being captured by CAPOC. Full implementation projections are based on the purchase of an additional three-channel transmitting ECG cart to capture ECGs done in the inpatient areas and having ECGs taken as part of annual physicals done by CAPOC. These changes would not increase the level of effectiveness over the Y Period level. However, the percent of ECGs meeting criteria for the preferred level of service would increase from 6 percent to 31 percent. This increase would be due to internists becoming preferred readers for normal ECGs.

Conclusions: Not all ECGs done at March are being catpured by CAPOC. CAPOC has not resulted, nor is it expected to result, in significant changes in the level of effective ECG services at this site.

F. LONG BEACH NAVAL REGIONAL MEDICAL CENTER

Long Beach Naval Regional Medical Center is a regional hospital with 129 authorized beds, which provides general medical and surgical services. The typical occupancy rate is 80 percent. The facility has an ICU with about 10 beds. The hospital has many specialty outpatient clinics and outpatient visits total approximately 510,000 in the X Period. The staff that reads ECGs consists of one cardiologist and five internists.

During the X Period the ECG Laboratory was located in the Internal Medicine Clinic and was staffed by five full-time technicians. There was one cardiologist on the hospital staff during the X Period. CAPOC was not implemented at Long Beach NRMC during the Y Period data collection because of delays in installing the required telephone interface.

In the X Period, routine ECGs were taken on Monday through Friday between 0800 and 1615 hours. On nights and weekends, ECGs were done in the Emergency Room and Intensive Care Unit. These ECGs were usually done by corpsmen and nurses working in these units who had been trained in the taking of ECGs. For the inpatient wards, an ECG technician from the Internal Medicine Clinic was on-call 24 hours a day to take ECGs. ECG equipment consisted of six carts (four three-channel transmitting carts and two single-channel carts), which were located in the ECG Laboratory and in patient care areas. When CAPOC is implemented, Long Beach NRMC will have an overread station located in the ECG Laboratory. They will be able to perform all functions related to editing, retrieval, etc.

A summary of quantitative data for this site is given in Table 4-11. The annual ECG volume in the X Period was 5,280 ECGs. This volume is not expected to change dramatically with CAPOC implementation. Table 4-12 summarizes the level of ECG service effectiveness in the X Period (and currently, without CAPOC) and when CAPOC is implemented. In the X Period, 96 percent of all ECGs met effective service criteria. This is only expected to increase to 98 percent with CAPOC implementation when the automated storage and retrieval of prior ECGs becomes operational. While the overall effectiveness will not change significantly, the percentage of ECGs meeting preferred criteria will increase from 2 percent in the X Period to 90 percent with the CAPOC system. This shift

TABLE 4-11

SUMMARY OF QUANTITATIVE DATA FOR
LONG BEACH NAVAL REGIONAL MEDICAL CENTER

	X Period	Projected
Volume	5,280	5,280
Type		
Routine Outpatient	66%	66%
Routine Inpatient	13%	13%
Pre-Operative	12%	12%
STAT/ER	9%	9%
Reader		
Cardiologist	15%	1.6%
Internist	85%	16.0%
Other	0	81.9%
Interpretation		
Normal	90%	90%
Abnormal	10%	10%

TABLE 4-12

SUMMARY OF IMPACTS OF CAPOC ON EFFECTIVENESS OF ECG SERVICES
AT LONG BEACH NAVAL REGIONAL MEDICAL CENTER

	Number of ECGs (Percent)		
	X Period	Y Period	Full Implementation
Reader			
Preferred	792 (15.0)	*	4,834 (91.5)
Acceptable	4,488 (85.0)		446 (8.5)
Turnaround Time			
Preferred	1,162 (22.0)	*	4,932 (93.4)
Acceptable	4,118 (78.0)		348 (6.6)
Abnormals with Serial Comparison	317 (60.0)	*	422 (80.0)
Conclusion			
Preferred	106 (2.0)	*	4,768 (90.3)
Acceptable	4,963 (94.0)		406 (7.7)
TOTAL	5,069 (96.0)	*	5,174 (98.0)

*Not implemented during Y Period data collection.

is due to changes in the definition of preferred readers for normal ECGs, improvements in turnaround time, and use of serial comparisons.

Conclusions: CAPOC was not implemented at Long Beach NRMC in the Y Period data collection. CAPOC is expected to increase the level of preferred services but not significantly affect the baseline effectiveness of services at Long Beach.

G. NAVAL STATION SAN DIEGO BRANCH CLINIC

The Naval Station San Diego Branch Clinic provides only general outpatient medical care. Patients requiring hospitalization or specialized diagnostic or therapeutic services are referred to San Diego NRMC. In the X Period, the staff consisted of nine physicians--one internist, one family practitioner, one occupational medicine specialist, one psychiatrist, and five civilian general practitioners. One general practitioner and the family practitioner left between the X and Y Periods so the Y Period staffing was reduced to seven.

The ECG Laboratory, in the Physical Examination Clinic, was staffed by one full-time technician in both periods. Routine ECGs were taken between 0730 and 1600 on Monday through Friday. On nights and weekends, patients were sent to San Diego NRMC for ECGs when required. In the X Period, there was a single-channel ECG machine in the ECG Laboratory. In the Y Period, the equipment consisted of a three-channel transmitting cart and CAPOC printer in the ECG Laboratory, and a three-channel ECG cart in the Emergency Room. The old single-channel ECG cart was kept for back-up. In the X Period, the ECG tracings were sent by guard mail to San Diego NRMC to be read. The tracing and interpretation were returned from two to seven days later.

Basic data on ECG volumes and types and on ECG readers are summarized in Table 4-13. The annual ECG volume in the X Period was 3,148. In the Y Period, the annual ECG volume decreased by 14 percent to 2,712. This decrease might be due to the decrease in physician staff that occurred between the two periods.

Table 4-14 summarizes the effectiveness of ECG services at the Naval Station in the X and Y Periods and for full implementation. In the X Period, 69 percent of all ECGs met effective service criteria. This number increased to 80 percent in the Y Period. The increase is due to improved turnaround time for return of ECG interpretations. When automated storage and retrieval of prior ECGs is available, the effectiveness of service is expected to increase to 96 percent because of an increase in the use of serial comparison for abnormal tracings.

The staff at the Naval Station likes the CAPOC system. The most important feature for them is the reduced turnaround time, especially

TABLE 4-13

SUMMARY OF QUANTITATIVE DATA FOR
NAVAL STATION SAN DIEGO BRANCH CLINIC

	X Period	Y Period
Volume	3,148	2,712
Type		
Routine Outpatient	20%	20%
Annual Physical	80%	80%
Reader		
Cardiologist	100%	20%
Internist	0	0
Other	0	80%
Interpretation		
Normal	80%	80%
Abnormal	20%	20%

TABLE 4-14

SUMMARY OF IMPACTS OF CAPOC ON EFFECTIVENESS OF ECG SERVICES
AT NAVAL STATION SAN DIEGO BRANCH CLINIC

	Number of ECGs (Percent)		
	X Period	Y Period	Full Implementation
Reader			
Preferred	3,148 (100.0)	2,712 (100.0)	2,712 (100.0)
Acceptable	0 (0)	0 (0)	0 (0)
Turnaround Time			
Preferred	409 (13.0)	2,604 (96.0)	2,604 (96.0)
Acceptable	2,298 (73.0)	108 (4.0)	108 (4.0)
Abnormals with Serial Comparison	0 (0)	0 (0)	434 (80.0)
Conclusion			
Preferred	315 (10.0)	2,170 (80.0)	2,517 (92.8)
Acceptable	1,857 (59.0)	0 (0)	87 (3.2)
TOTAL	2,172 (69.0)	2,170 (80.0)	2,604 (96.0)

for unconfirmed interpretations, which they feel improves patient care. Having the corpsmen screen normal and abnormal ECGs also saves time for the physicians.

Conclusions: CAPOC has improved ECG service effectiveness at the Naval Station because of improved turnaround time. Availability of prior ECGs for serial comparison will result in an even greater improvement.

H. NAVAL AIR STATION NORTH ISLAND BRANCH CLINIC

The Naval Air Station North Island is located on the northern tip of Coronado, across the San Diego-Coronado Bay Bridge from San Diego. The Branch Clinic provides outpatient and emergency services primarily for the active duty military and civilian workforce assigned to the facility. There are four specialty clinics - Occupational Health, General Military, Physical Examination and Ophthalmology. When other services are required, patients are referred to San Diego NRMC. When operating with non-automated services the clinic was staffed by 12 physicians--one occupational medicine specialist, 10 flight surgeons and one general medical officer. In the X Period there were 64,000 outpatient visits to the clinics.

Before automation, there was no formal ECG Laboratory at North Island. A three-channel Marquette Cart with a cassette recorder resided in the Physical Examination Clinic but was moved to wherever it was required. The cart was on loan from San Diego NRMC. A single-channel HP cart was used as a backup and to run ECG rhythm strips. All corpsmen were trained to take ECGs. ECGs were taken from 0730 to 1600 on Monday through Friday. The corpsman on duty in the emergency room was responsible for ECGs required outside these hours. In the X Period, the annual ECG volume at North Island was 3149 (Table 4-15). The CAPOC system was not operational at North Island during the Y Period data collection effort conducted in the fall of 1980. This was attributed primarily to malfunctions of the (old) ECG cart that had not been resolved despite repeated efforts by the repairmen. Therefore, during the Y Period data collection, operation of the ECG process at North Island was unchanged from the baseline. Table 4-15 summarizes data concerning ECG types and readers for this site.

Table 4-16 summarizes ECG service effectiveness with manual services (X Period and currently) and the projected values when the system is fully implemented. With non-automated services, all non-emergency ECGs were sent to San Diego NRMC to be read. Emergency ECGs were taken at North Island and then the patient with his ECG was sent to San Diego NRMC where the ECG was read and the patient evaluated. Using this process,

TABLE 4-15

SUMMARY OF QUANTITATIVE DATA FOR
NAVAL AIR STATION NORTH ISLAND BRANCH CLINIC

	X Period	Projected
Volume	3,149	3,149
Type		
Routine Outpatient	20%	20%
Annual Physical	75%	75%
STAT/ER	5%	5%
Reader		
Cardiologist	95%	10%
Internist	0	0
Other	5%	90%
Interpretation		
Normal	90%	90%
Abnormal	10%	10%

TABLE 4-16

SUMMARY OF IMPACTS OF CAPOC ON EFFECTIVENESS OF ECG SERVICES
AT NAVAL AIR STATION NORTH ISLAND BRANCH CLINIC

	Number of ECGs (Percent)		
	X Period	Y Period	Full Implementation
Reader			
Preferred	2,992 (95.0)	*	3,149 (100.0)
Acceptable	157 (5.0)		0 (0)
Turnaround Time			
Preferred	331 (10.5)	*	3,070 (97.5)
Acceptable	2,236 (71.0)		63 (2.0)
Abnormals with Serial Comparison	0 (0)	*	252 (80.0)
Conclusion			
Preferred	299 (9.5)	*	3,023 (96.0)
Acceptable	1,905 (60.5)		50 (1.6)
TOTAL	2,204 (70.0)	*	3,073 (97.6)

*Not implemented during Y Period data collection.

70 percent of all ECGs met effective service criteria.

When CAPOC becomes operational at North Island, the percent of ECGs meeting effective service criteria is expected to increase to 98 percent. This requires that all ECGs be captured by CAPOC and that 80 percent of abnormal ECGs receive a serial comparison when the automated storage and retrieval capability is fully operational.

Conclusions: The CAPOC system was not operational at North Island in the fall of 1980 due to reliability problems with their old ECG cart. Service effectiveness is expected to increase with automation when this problem is solved and when automatic storage and retrieval of ECGs is available on the CAPOC system.

I. NAVAL TRAINING CENTER BRANCH CLINIC

The Naval Training Center Branch Clinic (NTC) is an outpatient clinic located in San Diego. There were six physicians at NTC--one internist and five general medical officers--during the X Period. The internist left between the X and Y Period site visits so staffing was reduced to five general medical officers in the Y Period. Specialty clinics are staffed by physicians from San Diego NRMC. Patients requiring specialized care and services are referred to San Diego NRMC.

In the X and Y Periods organization of the ECG process was similar. The ECG Laboratory was located in the Physical Examination Clinic. ECGs were taken from 0730 to 1600 on Monday through Friday. ECGs were available in the emergency room at night and on weekends. However, most patients with cardiac symptoms were sent to the emergency room at San Diego NRMC.

The ECG Laboratory was staffed by one full-time technician during the X Period. This person did not, however, devote full-time to ECGs. In the Y Period, approximately 10 corpsmen were responsible for taking ECGs on a part-time, rotating basis. The ECG equipment at NTC did not change as a result of CAPOC implementation. NTC purchased a three-channel transmitting ECG cart in 1977 in anticipation of CAPOC. A three-channel, non-transmitting ECG cart, purchased in 1975, was kept for back-up use. The CAPOC printer is located in the ECG Laboratory.

The annual ECG volume as measured by logs kept at the facility in the X Period was 1307 ECGs (Table 4-17). This increased by 29 percent in the Y Period to 1679 ECGs. However, only 31 percent of these ECGs were being processed by CAPOC in the fall of 1980 when Y Period data collection occurred. A lack of training and the high turnover rate of technician staff were given as reasons for this low level of system utilization.

Tables 4-17 and 4-18 summarize basic data on ECG types, turnaround time and ECG reading and the impacts of CAPOC on ECG services at NTC. In the X Period 12 percent of the ECGs met effective service criteria. This represents the ECGs read by the internist. In the Y Period 24 percent of the ECGs met effective service criteria. This change is due to the general medical officers becoming preferred readers for those ECGs

TABLE 4-17

SUMMARY OF QUANTITATIVE DATA FOR
NAVAL TRAINING CENTER BRANCH CLINIC

	X Period	Y Period
Volume	1,302	1,679
Type		
Routine Outpatient	20%	20%
Annual Physical	80%	80%
Reader		
Cardiologist	0	0
Internist	12%	7.4%
Other	88%	92.6%
Interpretation		
Normal	95%	76%
Abnormal	5%	24%

TABLE 4-18

SUMMARY OF IMPACTS OF CAPOC ON EFFECTIVENESS OF ECG SERVICES
AT NAVAL TRAINING CENTER BRANCH CLINIC

	Number of ECGs (Percent)		
	X Period	Y Period	Full Implementation
Reader			
Preferred	0 (0)	520 (31.0)	1,679 (100.0)
Acceptable	156 (12.0)	0 (0)	0 (0)
Turnaround Time			
Preferred	1,302 (100.0)	1,637 (97.5)	1,545 (92.0)
Acceptable	0 (0)	42 (2.5)	134 (8.0)
Abnormals with Serial Comparison	39 (60.0)	167 (41.4)	322 (80.0)
Conclusion			
Preferred	0 (0)	396 (23.6)	1,491 (88.8)
Acceptable	156 (12.0)	0 (0)	107 (6.4)
TOTAL	156 (12.0)	396 (23.6)	1,598 (95.2)

processed by CAPOC. It is projected that, with full implementation of CAPOC, 95 percent of all ECGs will meet effective service criteria. This projection is based on two assumptions: all ECGs done at NTC will be processed by CAPOC and 80 percent of abnormals will receive a serial comparison when the automatic storage and retrieval capability is operating.

The NTC staff indicated that they are satisfied with CAPOC, when it is used. They especially liked the rapid turnaround time for unconfirmed interpretations. They would like to see more frequent training of technicians. (A change from part-time back to a full-time ECG technician might also help in solving the problem of low utilization due to lack of technician training in system use.)

Conclusions: The overall effectiveness of ECG services as measured by the criteria increased despite the internist leaving and only 31 percent of the ECGs being processed by CAPOC. Service effectiveness should increase even more upon full implementation. A more frequent training program is needed to insure that all technicians can use the CAPOC system, and, thus, that all ECGs taken at this site will be processed by CAPOC.

J. NAVAL AMPHIBIOUS BASE CORONADO BRANCH CLINIC

The Naval Amphibious Base Coronado Branch Clinic (Coronado) is an outpatient dispensary located about four miles from San Diego across the San Diego-Coronado Bay Bridge. The population served is predominantly dependents of active-duty military and retired personnel. The facility was staffed by nine general practitioners in both the X and Y data collection periods. Several specialty clinics, staffed on a part-time basis by physicians from San Diego NRMC, are provided at Coronado. Patients with special problems or in need of hospitalization are referred to San Diego NRMC. Outpatient visits totaled 67,000 in the X Period and 73,000 in the Y Period, an increase of 9 percent.

The process for taking ECGs at Coronado was the same in the X and Y data collection periods. The ECG Laboratory, open from 0800 to 1500 on Monday through Friday, was staffed by one full-time technician and one additional corpsman who spent about 20 percent of the time taking ECGs. ECGs were done in the Emergency Room at night and on weekends. ECG equipment was also the same before and after CAPOC implementation. A three-channel transmitting cart was purchased in 1978 in anticipation of CAPOC. A single-channel ECG cart, purchased in 1972, was kept for back-up use. The CAPOC printer is located in the ECG Laboratory.

The process of reading ECGs taken at Coronado changed between the X and Y Periods. In the X Period, ECGs taken as part of annual physical examinations were sent to San Diego NRMC to be read by the cardiology staff. STAT ECGs and ECGs for routine outpatient visits were read by the ordering physician. In the Y Period, all ECGs were read by a cardiologist at San Diego NRMC. (Emergency Room ECGs were also read immediately by the requesting physician.)

Table 4-19 presents data on ECG volumes and types and ECG reading. In the X Period, the ECG volume was 1,200. This volume increased by 5 percent in the Y Period to 1,307 ECGs. This increase is consistent with the increase in outpatient visits that occurred during the same time period.

Table 4-20 summarizes the measured and projected levels of effective ECG services at Coronado. In the X Period, 9 percent of all ECGs

TABLE 4-19

SUMMARY OF QUANTITATIVE DATA FOR
NAVAL AMPHIBIOUS BASE CORONADO BRANCH CLINIC

	X Period	Y Period
Volume	1,200	1,307
Type		
Routine Outpatient	48%	59%
Annual Physical	50%	39%
STAT/ER	2%	2%
Reader		
Cardiologist	50%	31.4%
Internist	0	0
Other	50%	68.6%
Interpretation		
Normal	92%	66.3%
Abnormal	8%	33.7%

TABLE 4-20

SUMMARY OF IMPACTS OF CAPOC ON EFFECTIVENESS OF ECG SERVICES
AT NAVAL AMPHIBIOUS BASE CORONADO BRANCH CLINIC

	Number of ECGs (Percent)		
	X Period	Y Period	Full Implementation
Reader			
Preferred	600 (50.0)	1,297 (99.2)	1,297 (99.2)
Acceptable	0 (0)	0 (0)	0 (0)
Turnaround Time			
Preferred	24 (2.0)	999 (76.4)	999 (76.4)
Acceptable	108 (9.0)	308 (23.6)	308 (23.6)
Abnormals with Serial Comparison	72 (75.0)	6 (1.5)	335 (79.5)
Conclusion			
Preferred	0 (0)	886 (67.8)	967 (74.0)
Acceptable	108 (9.0)	0 (0)	247 (18.9)
TOTAL	108 (9.0)	886 (67.8)	1,214 (92.9)

met effective service criteria before CAPOC was installed. This had increased to 68 percent in the Y Period in the fall of 1980 after CAPOC had been in use for 9 months. The increase can be attributed to the general practitioners being classified as preferred readers for confirming computer-generated normal ECG interpretations and a decrease in turnaround time for the routine ECGs (those not done in the Emergency Room). In the Y data collection period, use of serial comparison had dropped because the system's automatic storage and retrieval capability was not in operation. Only Emergency Room ECGs had a serial comparison. At full implementation of CAPOC, it is projected that 93 percent of all ECGs at Coronado will meet effective service criteria. This change will occur solely from 80 percent of non-emergency ECGs that are abnormal receiving a serial comparison when the automatic storage and retrieval feature is fully operational.

Physicians at Coronado reported that they like the CAPOC system, especially the rapid turnaround time for return of unconfirmed interpretations. Also, the typed, confirmed interpretations were more legible than the handwritten reports received in the X Period. The ECG technician also liked the CAPOC system. She believed that CAPOC provided better organization and resulted in fewer lost ECGs. She did not believe it had decreased total time devoted to the ECG process by technicians.

Conclusions: CAPOC has resulted in a dramatic increase in service effectiveness. The general practitioners became preferred readers for normal ECGs and the turnaround time decreased for ECGs done as part of annual physicals examinations.

K. MARINE CORPS RECRUIT DEPOT BRANCH CLINIC

The Marine Corps Recruit Depot (MCRD) Branch Clinic is an outpatient facility on a recruit training base in San Diego. Outpatient visits were approximately 129,000 in the X Period and dropped to slightly over 124,000 in the Y Period. The medical staff consisted of four full-time general practitioners in both periods. Specialists from San Diego NRMC staffed the specialty clinics on a part-time basis.

Both before and after CAPOC was installed, the ECG Laboratory, located in the General Practice Clinic, was staffed by nine part-time technicians. ECGs were taken Monday through Friday from 0730 to 1600. There was a corpsman on duty to take ECGs during nights and weekends.

A three-channel Marquette 3000 transmitting cart was purchased in 1976 in anticipation of CAPOC. A single-channel ECG cart, purchased in 1977, was kept for back-up use. A printer, for use with CAPOC was located in the ECG Laboratory.

Basic data on ECG volumes and types and specialized training of ECG readers are summarized in Table 4-21. In the X Period the annual ECG volume at MCRD was 900. This number decreased to 750 in the Y Period. Some of this change might be related to the drop in outpatient visits; the change may also be due to more accurate reporting by the CAPOC system.

The impacts of CAPOC on MCRD for the X Period, Y Period and full implementation are given in Table 4-22. Before automation, physicians at MCRD read all their own ECGs. Since these readers did not meet the criterion for effective readers, no ECGs met effective service criteria during the X Period. With CAPOC, however, ECGs were being read by the cardiologists at San Diego NRMC and unconfirmed interpretations were available to the physicians at MCRD. The general practitioners at MCRD met preferred criteria for ECG reader when confirming normal interpretations generated by CAPOC. These ECGs were also available in a preferred turnaround time. The cardiologists at San Diego NRMC were preferred readers for abnormal ECGs. These were available within an acceptable time for routine outpatients and within a preferred time for ECGs done as part of annual physicals. However, no serial comparisons were available during the Y Period data collection because the automated storage and retrieval

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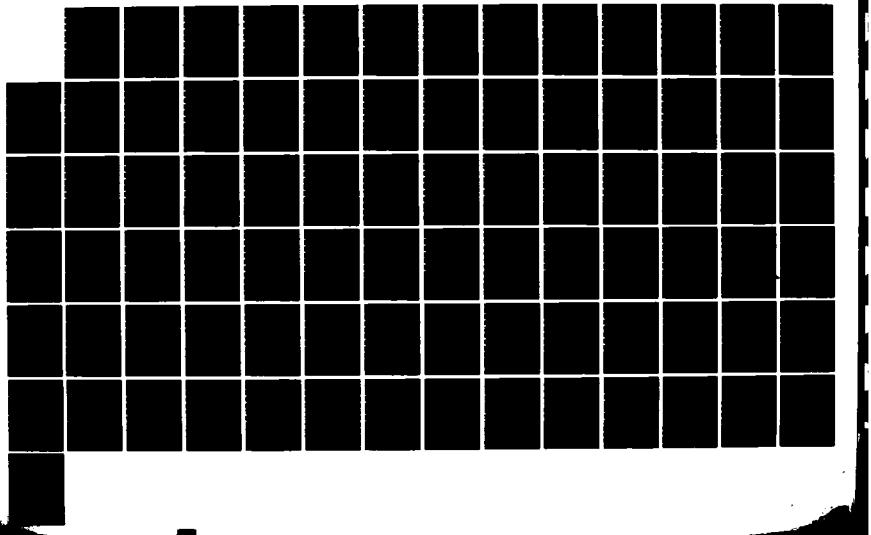


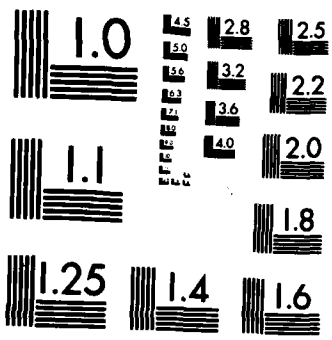


TABLE 4-21

SUMMARY OF QUANTITATIVE DATA FOR
MARINE CORPS RECRUIT DEPOT BRANCH CLINIC

	X Period	Y Period
Volume	900	750
Type		
Routine Outpatient	48%	46%
Annual Physical	47%	52%
STAT/ER	5%	2%
Reader		
Cardiologist	0	28.8%
Internist	0	0
Other	100%	71.2%
Interpretation		
Normal	95%	70.1%
Abnormal	5%	29.9%

TABLE 4-22

SUMMARY OF IMPACTS OF CAPOC ON EFFECTIVENESS OF ECG SERVICES
AT MARINE CORPS RECRUIT DEPOT BRANCH CLINIC

	Number of ECGs (Percent)		
	X Period	Y Period	Full Implementation
Reader			
Preferred	0 (0)	743 (99.0)	743 (99.0)
Acceptable	0 (0)	0 (0)	0 (0)
Turnaround Time			
Preferred	468 (52.0)	612 (81.6)	612 (81.6)
Acceptable	432 (48.0)	138 (18.4)	128 (18.4)
Abnormals with Serial Comparison	27 (60.0)	5 (2.0)	177 (79.3)
Conclusion			
Preferred	0 (0)	527 (70.2)	589 (78.5)
Acceptable	0 (0)	0 (0)	110 (14.7)
TOTAL	0 (0)	527 (70.2)	699 (93.2)

capabilities of the system were not operational. Changes introduced by CAPOC resulted in 70 percent of all ECGs meeting effective service criteria in the Y Period. When automated storage and retrieval for serial comparison becomes operational, it is estimated that 80 percent of abnormal ECGs will receive a serial comparison. This change will mean that 93 percent of all ECGs at MCRD will meet effective service criteria upon full implementation of CAPOC.

Physicians at MCRD reported that they liked the CAPOC system, especially the rapid turnaround time for the unconfirmed interpretation. Their reliance on the unconfirmed interpretation was increasing as they became more experienced with the system.

The only problem identified during the Y Period site visit was with training of corpsmen. Some of this problem was due to the high turnover rate of corpsmen at the facility and the infrequent schedule of formal CAPOC training programs.

Conclusions: CAPOC has resulted in improvements in ECG services at the Marine Corps Recruit Depot. Seventy-two percent of all ECGs met criteria for effective ECG services whereas, in a manual mode, no ECGs met the criteria. When automated storage and retrieval of old tracings is available, 93 percent of all the ECGs at MCRD will meet criteria for effective services.

L. PORT HUENEME NAVAL REGIONAL MEDICAL CLINIC

Port Hueneme is located approximately 50 miles northwest of Los Angeles and just south of Oxnard, California. The Naval Regional Medical Clinic at this facility provides outpatient medical care only. Emergency cases are sent to the nearby local civilian hospital. Other patients requiring specialized care are referred to Long Beach Naval Regional Medical Center. At the time of the Y Period site visit, there were 11 physicians on the staff--one internist, eight general medical officers, and two pediatricians. One internist and the flight surgeon left and one general medical officer was assigned to the clinic between the X and Y Period site visits.

The ECG Laboratory was located in the Internal Medicine Clinic. In the X Period, responsibilities for ECGs were rotated among the nurses and corpsmen at the clinic, on a two-week basis. This arrangement changed in the Y Period such that a civilian RN was responsible for the Laboratory. In addition, during the Y Period, a corpsman, assigned to duty in the Internal Medicine Clinic, could also take ECGs. With manual services, ECG interpretations were typed after being dictated by the internist. With CAPOC, this activity had been eliminated. The CAPOC interprepation was attached to the ECG. Prior ECGs continued to be filed in the Internal Medicine Clinic after CAPOC implementation.

The clinic had a three-channel transmitting Hewlett-Packard ECG cart in the X Period, and a printer was added to the ECG Laboratory in the Y period. The ECG cart was purchased in 1977 in anticipation of CAPOC. No additional equipment at the site could be interfaced with CAPOC. There were two single-channel ECG machines--one in the Internal Medicine Clinic, and one in the treatment area. In both periods, these were for use by reservists on weekends. ECGs were taken between 0730 and 1600, Monday through Friday, in both periods. Patients are referred to the local hospital when an ECG is required outside these hours.

The annual volume of ECGs done at Port Hueneme for fiscal year 1979 was 1699; it decreased in fiscal year 1980 to 1313 ECGs. (Table 4-23)

This decrease is attributed to a decrease in physician staff, and the change to a clinic from a hospital (which closed in June, 1979).

A summary of the basic data and impacts of CAPOC on Port Hueneme Naval Regional Medical Clinic are shown in Tables 4-23 and 4-24. During X Period data collection, no data were available on types of ECGs, serial comparison, etc.; rather, interviews were relied upon for necessary breakdowns. In the Y Period data collection, logs were available that contained the necessary information. Using data on serial comparisons, percent normals and types of ECGs, 85.5 percent of all ECGs met effective service criteria in X and Y. However, the split between preferred and acceptable ECGs did change. The internist became a preferred reader and turnaround time improved because ECG reports were no longer delayed by typing. This resulted in 13.1 percent of ECGs meeting criteria for preferred services. Breakdowns on ECG types and serial comparisons collected in the Y Period were applied to the X Period. It was felt that these data were more reliable than estimates provided by interviews with various personnel at the facility. However, if the staff estimates were correct in the X Period, 92 percent of all ECGs would have met effective service criteria.

At full implementation, it is projected that 93.5 percent of all ECGs will meet effective criteria. This would require that the patient be given a copy of the unconfirmed interpretation to take back to the requesting physician. It would also require that all abnormal ECGs be read by the cardiologist at Long Beach Naval Regional Medical Center and 80 percent of these receive a serial comparison.

The staff at Port Hueneme NRMC likes the CAPOC system. They report that it gives them confidence in reading and serves to make them more aware of various subtle points that they may miss in reading. The internist believes it reduces reading time for him.

There is some problem with the operational aspects of the system. Often the printer is turned off and the central system continually dials the site, but the unconfirmed interpretation is not received. This problem, attributed to a lack of technician training, will hopefully be resolved when the CAPOC training program is fully operational.

TABLE 4-23

SUMMARY OF QUANTITATIVE DATA FOR
PORT HUENEME NAVAL REGIONAL MEDICAL CLINIC

	X Period	Y Period
Volume	1,699	1,313
Type		
Routine Outpatient	82.5%	82.5%
Annual Physical	17.5%	17.5%
Reader		
Cardiologist	0	5.5%
Internist	100%	26.9%
Other	0	67.6%
Interpretation		
Normal	67.6%	67.6%
Abnormal	32.4%	32.4%

TABLE 4-24

SUMMARY OF IMPACTS OF CAPOC ON EFFECTIVENESS OF ECG SERVICES
AT PORT HUENEME NAVAL REGIONAL MEDICAL CLINIC

	Number of ECGs (Percent)		
	X Period	Y Period	Full Implementation
Reader			
Preferred	0 (0)	887 (67.6)	960 (73.1)
Acceptable	1,699 (100.0)	426 (32.4)	353 (26.9)
Turnaround Time			
Preferred	85 (5.0)	230 (17.5)	945 (71.9)
Acceptable	1,614 (95.0)	1,083 (82.5)	368 (28.1)
Abnormals with Serial Comparison	305 (55.3)*	235 (55.3)	341 (80.0)
Conclusion			
Preferred	0 (0)	172 (13.1)	895 (68.2)
Acceptable	1,453 (85.5)	951 (72.4)	332 (25.3)
TOTAL	1,453 (85.5)*	1,123 (85.5)	1,227 (93.5)

*If serial comparisons had been 80 percent as estimated by the staff in the X Period, the conclusion would have been that 92.0 percent (1,563 ECGs) met criteria for effective service.

Conclusions: Overall, ECG service effectiveness did not change at Port Hueneme after the implementation of CAPOC. However, some of the ECGs meeting acceptable service criteria in the X Period met preferred service criteria in the Y Period. Full implementation is expected to increase the overall service effectiveness.

M. BARSTOW BRANCH CLINIC

Barstow Branch Clinic is an outpatient facility located about 70 miles north of San Bernardino. This clinic provides general outpatient medical services. Patients requiring diagnostic or therapeutic services that are not available at Barstow are referred to Camp Pendleton Naval Regional Medical Center or, in emergencies, to local civilian hospitals. The staff consists of four general practitioners.

Before CAPOC was installed, the ECG Laboratory was located in a small room adjacent to the Emergency Room. It was staffed by seven part-time technicians. ECGs were done on Monday through Friday from 0700 to 1530 hours. On nights and weekends, ECGs were taken by the corpsman assigned to the ER. There was a three-channel Hewlett-Packard, Model 1517A, transmitting cart located in the ECG room adjacent to the ER. In addition, there was a one-channel machine kept for use as a back-up.

CAPOC had not been implemented at this site during the Y Period site visits. They were still experiencing difficulties in transmitting ECGs and with the operation of their ECG cart. However, the ECG process is not expected to change significantly when CAPOC is implemented.

For the year October, 1978, to September, 1979, approximately 860 ECGs were taken at Barstow (Table 4-25). This figure was estimated based upon the log book and interviews with staff. According to estimates of the physician staff, about 45 percent of the ECGs were taken for routine outpatient examinations, 50 percent as part of annual physical examinations, and 5 percent for emergency patients. It is assumed that these breakdowns and volumes will not change when CAPOC is eventually implemented.

Summaries of basic data and the projected impacts of CAPOC compared with X Period manual services are given in Tables 4-25 and 4-26. No ECGs met effective service criteria when using non-automated services. When full implementation occurs, it is estimated that almost 100 percent of all ECGs will meet effective service criteria. The increase will result from two changes. The general medical officers will become preferred readers for all normal ECGs, estimated at 99 percent of the volume.

TABLE 4-25

SUMMARY OF QUANTITATIVE DATA FOR
BARSTOW BRANCH CLINIC

	X Period	Projected
Volume	860	860
Type		
Routine Outpatient	45%	45%
Annual Physical	50%	50%
Pre-Operative	5%	5%
Reader		
Cardiologist	0	0.1%
Internist	0	0.9%
Other	100%	99.0%
Interpretation		
Normal	99%	99%
Abnormal	1%	1%

TABLE 4-26

SUMMARY OF IMPACTS OF CAPOC ON EFFECTIVENESS OF ECG SERVICES
AT BARSTOW BRANCH CLINIC

	Number of ECGs (Percent)		
	X Period	Y Period	Full Implementation
Reader			
Preferred	0 (0)	*	852 (99.1)
Acceptable	0 (0)		8 (0.9)
Turnaround Time			
Preferred	860 (100.0)	*	856 (99.5)
Acceptable	0 (0)		4 (0.5)
Abnormals with Serial Comparison	0 (0)	*	7 (80.0)
Conclusion			
Preferred	0 (0)	*	851 (99.0)
Acceptable	0 (0)		6 (0.7)
TOTAL	0 (0)	*	857 (99.7)

*Not implemented during Y Period data collection.

Cardiologists at Camp Pendleton will provide interpretations for abnormal ECGs as well as serial comparisons for 80 percent of abnormal ECGs. (This assumes that the automated storage and retrieval capability is available.)

Conclusions: When CAPOC services are available, they will result in an increase of the effectiveness of ECG services at Barstow Branch Clinic.

CHAPTER 5. RESULTS

A. IMPACT OF CAPOC ON EFFECTIVENESS OF ECG SERVICE

The primary objective in installing the CAPOC system is to improve ECG services in the 18 CAPOC sites in the region. To be useful, an ECG interpretation must be accurate, and must be available when needed for the diagnosis and treatment of the patient. For this evaluation, an effective ECG was defined as one that is read by a qualified reader, is returned to the requesting physician within a prescribed time, and is compared with a prior interpretation if the current ECG is abnormal. As described in Chapter 2, the required turnaround time depends on the type of patient being treated, and hence, the way the ECG is used. ECGs for emergency patients are needed within minutes so that the physician can reflect the results in immediate decisions that have to be made concerning patient management, whereas screening ECGs taken as part of annual physical examinations are required within a few days of the examination.

Two effectiveness parameters--reading quality and availability of the interpretation--were identified as the most important service criteria by potential users in the region, and by the review panel. (Reading quality includes both the training of the reader and use of serial comparison for abnormal ECGs.) Therefore, these parameters were the focus of data collection and are discussed in detail here. Other aspects of high-quality ECG services were evaluated in a qualitative manner and those findings are discussed in Section D of this chapter.

In order to evaluate the key service criteria of reader, turnaround time, and use of serial comparison, two levels of service were defined--acceptable service and preferred service. These two levels together comprise effective services. The criteria for each service level are discussed in detail in Chapter 2. The percentage of ECGs meeting each service level were determined under manual operations (X Period) in the Fall of 1979; in the Fall of 1980 when the system was partially operational (Y Period); and then were projected for the system when effectiveness has been maximized by resolution of remaining technical problems and adoption of operational changes at some sites (full implementation).

The results of the analysis of ECGs meeting effective service criteria are shown in Table 5-1, which lists the 18 sites in order of decreasing ECG volume, and grouped into two categories, large sites and small sites. Large sites are those sites with more than 100 beds and/or more than 200,000 outpatient visits per year.

The table presents data on the percentage of the ECGs at each site that met effective service criteria in the X and Y evaluation periods, and the percentage of ECGs that are projected to meet the criteria when CAPOC has been fully implemented. Before the implementation of CAPOC, 50% of all ECG services in the region met the criteria for effective ECG services: 56 percent of the ECGs in the large sites and 38 percent of those in small sites.[12]

The table also shows the service elements that inhibited achievement of effective service levels in each site. In large facilities, turnaround time to receive the interpretation and use of serial comparison were the most common problem areas. This is because large sites have a high percentage of abnormal ECGs, which require a serial comparison and a high percentage of emergency, pre-operative, and inpatient ECGs, which require rapid turnaround for an interpretation. When ECGs were processed manually at small sites without cardiologists or internists on the staff, the tracings were typically read by a general practitioner because it took too long to receive an interpretation from a large site by mail. Therefore, a large number of ECGs at these sites did not meet the criteria for effective reader. In small sites where ECGs were sent outside to be read, services did not meet criteria for effective turnaround time.

When the CAPOC system is fully operational, effectiveness of services in the region will increase from 50 percent to 78 percent over the entire region. The most dramatic increase in effectiveness will occur

[12] These ECGs were read by a qualified reader, were returned within the specified time limits, and received a serial comparison if abnormal. An ECG had to meet all three of these service criteria in order to be considered effective.

TABLE 5-1

EFFECTIVENESS OF ECG SERVICES
IN THE SOUTHERN CALIFORNIA AREA--X PERIOD, Y PERIOD, AND FULL IMPLEMENTATION

Site	ECG Volume		% of ECG's Meeting all Effective Service Criteria			Performance of Individual Service Elements*								
						Reader			Turnaround Time			Use of Serial Comparison		
	X	Y/Full	X	Y	Full	X	Y	Full	X	Y	Full	X	Y	Full
Large Sites														
San Diego NRMC	27,818	24,032	57	14	62	100	100	100	81	38	69	70	39	88
Camp Pendleton NRMC	12,000	12,000	26	27	83	100	100	100	34	35	95	64	64	87
USAFH, March	6,000	6,000	83	84	84	100	100	100	94	94	94	88	89	89
Long Beach NRMC	5,280	5,280	96	96	98	100	100	100	100	100	100	96	96	98
USAFH, Nellis.	3,900	3,417	41	59	84	90	92	93	62	73	99	70	78	90
Total/Average - Large Sites	54,998	50,729	56	37	75	99	99	99	73	52	83	73	59	89
Small Sites														
USAFH, Edwards	3,780	3,780	25	28	78	32	35	85	100	100	100	86	86	86
NAS, North Island	3,149	3,149	70	70	98	100	100	100	81	81	100	90	80	98
Naval Station, San Diego	3,148	2,712	69	80	96	100	100	100	86	100	100	80	80	96
USAFH, Vandenberg	2,808	2,808	57	57	76	74	74	94	94	94	94	84	84	84
USAFMF, Norton	2,280	2,426	0	40	63	0	40	64	95	98	98	75	75	75
Port Hueneme NRMC	1,699	1,313	86	86	94	100	32	100	100	100	100	92	86	94
USAFH, George	1,332	1,496	63	63	63	100	100	100	78	77	78	80	80	80
NTC Branch Clinic	1,302	1,679	12	24	95	12	31	100	100	100	100	98	86	95
NAB Coronado	1,200	1,307	9	68	93	50	99	99	11	100	100	98	68	93
Miramar NAS	1,320	1,320	0	70	93	0	99	99	100	100	100	100	71	94
29 Palms Branch Hospital	1,200	1,200	0	0	95	0	0	99	100	100	100	92	92	96
MCRD Branch Clinic	900	750	0	70	93	0	99	99	100	100	100	98	71	94
Barstow Branch Clinic	860	860	0	0	100	0	0	100	100	100	100	99	99	100
Total/Average - Small Sites	24,978	24,800	38	52	86	54	68	94	89	95	94	88	81	90
Regional Totals/Averages	79,976	75,529	50	41	78	85	89	98	78	67	88	78	67	89

*Percentage of ECGs meeting criteria.

X - Refers to X Period when manual ECG services were in use

Y - Refers to Y Period, one year following installation of CAPOC system

Full - Refers to projections of effectiveness when changes have been made which will result in achieving maximum benefits from CAPOC

at small sites, where effectiveness will more than double from 38 percent to 86 percent.

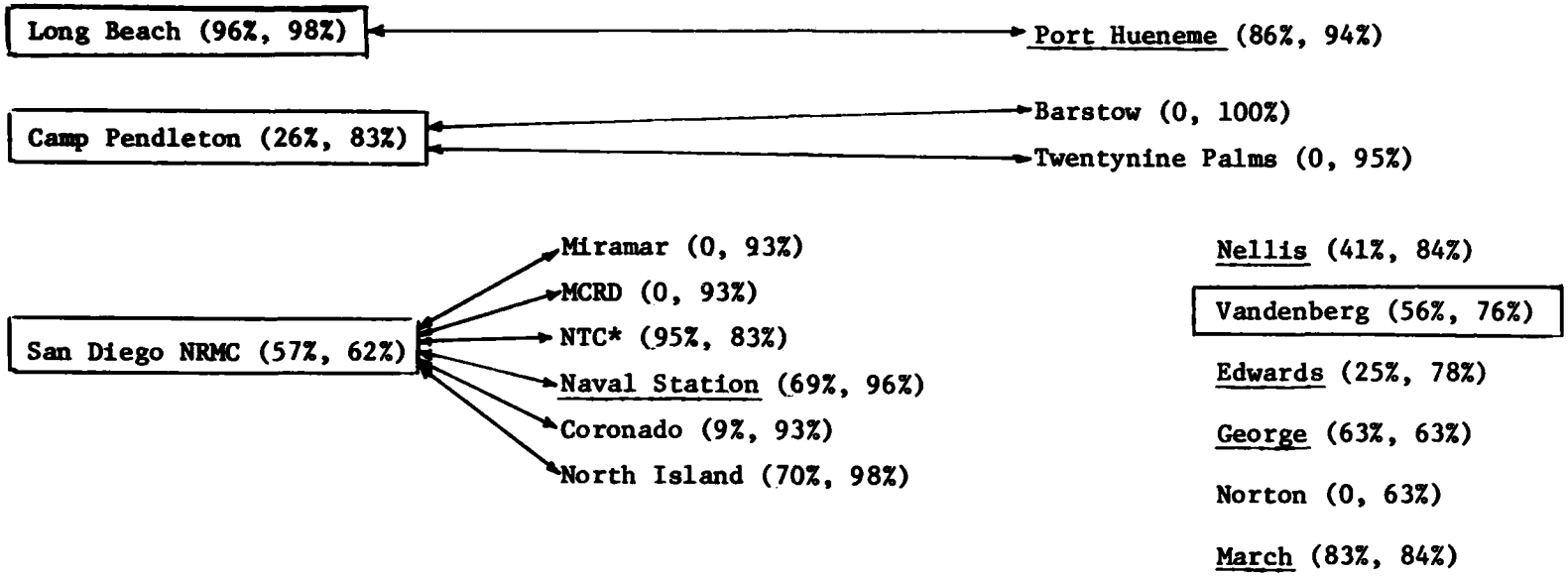
At large sites, the increase in effectiveness of services after automation is primarily due to the increased availability of prior ECG tracings that results from the automated storage and retrieval of ECGs by CAPOC. Misfiled records contribute to reduced effectiveness of manual ECG services. In one large site, 80 ECGs were identified for which the patient indicated that a prior ECG had been taken at the site, but for which no ECG file was found by the corspman. For 48 percent of these, a search through the files revealed that there was indeed an ECG folder for the patient in the general area where the file should have been located. The computer system will eliminate the problem of misfiling.

At all sites the system will also decrease turnaround time to receive some types of interpretations, for instance, normal ECGs will be considered available as soon as the requesting physician receives the computer report within minutes of the time the tracing is taken.

At small sites the most important aspect of CAPOC service is providing rapid access to computer-generated reports for normal ECGs. Because of the accuracy of the system in interpreting normal tracings[13] a general practitioner, flight surgeon, or corpsman is considered qualified to confirm a normal computer report. At small facilities most electrocardiograms taken are normal; hence, the percentage of ECGs meeting criteria for effective reader and turnaround time will increase dramatically after automation. Small sites linked to a large facility with specialized readers (cardiologists or internal medicine specialists) receive the greatest benefit from automation because the abnormal ECGs will have both effective readers and turnaround times.

Figure 5-1 illustrates the projected increase in effectiveness of ECGs services after automation and the resulting effectiveness levels at each site. Small sites without cardiologists on their staff, which are linked to large hospitals via the automated system, experience

[13] A. D. Hagen and J. S. Alper, "Evaluation of Computer Programs for Clinical Electrocardiography." Circulation 51-52, Suppl. II-193, 1975.



Codes:

Staffing: Cardiologists / Internists

⟷ Sites which are Linked for the Purpose of Overreading Services

(%, %) - Percent of ECGs Meeting Effectiveness Criteria in the X Period, and at Full Implementation

*The only internist on the staff at NTC in the X Period had been transferred and not replaced when Y Period data were collected.

FIGURE 5-1 EFFECTIVENESS OF ECG SERVICES - X PERIOD AND FULL IMPLEMENTATION

dramatic increases in service effectiveness. The CAPOC system clearly meets the objective of improving ECG services at MTFs without a cardiology staff.

The impact of the CAPOC system on service effectiveness is even more dramatic when the percentage of ECGs meeting preferred service levels--the more stringent criteria--are examined. As shown in Table 5-2, the percentage of ECGs in the region meeting these criteria before the implementation of CAPOC was very low--7 percent. After CAPOC has been fully implemented, the level will increase to 51 percent. The most dramatic increases are again at small sites, where rapid availability of the computer interpretation increases the effectiveness of the ECG interpretation in patient care--especially for normal electrocardiograms.

B. COST OF ECG SERVICES

The cost of ECG services for the X Period and when CAPOC is fully implemented were determined based on the volume of ECGs processed in each period. The costs of ECG services in the X Period are summarized by site and cost element in Table 5-3. In the X Period, the total cost of ECG service was $592,776 or $7.41 per ECG processed. Of this total, $6.54 represented variable costs--labor and supplies--and the remaining $0.87 represented fixed costs for equipment.

The differential cost analysis performed to determine the cost of CAPOC focused on two areas:

- additional costs due to new equipment purchased (both at the sites and for the central system) and those costs due to different types of supplies and usage, and
- cost savings attributable to reduction in labor time devoted to obtaining and reading ECGs and to elimination of various types of supplies.

Not all costs or savings are realized at each site due to the manner in which the ECG process and overreading occur. The costs and savings were only attributed to those sites where they are expected to occur. Thus, the estimate of differential costs is a conservative one. Tables

TABLE 5-2.

ECGs MEETING PREFERRED LEVELS OF SERVICE
IN THE SOUTHERN CALIFORNIA AREA--X PERIOD, Y PERIOD, AND FULL IMPLEMENTATION

Site	ECG Volume		% of ECG Volume Meeting All Criteria for Preferred Service			Performance on Individual Preferred Service Elements*								
						Reader			Turnaround Time			Use of Serial Comparison		
	X	Y/Full	X	Y	Full	X	Y	Full	X	Y	Full	X	Y	Full
Large Sites														
San Diego NRMC	27,818	24,032	16	6	45	83	90	90	34	19	57	70	39	88
Camp Pendleton NRMC	12,000	12,000	0	6	20	11	24	46	15	15	42	64	64	87
USAFH, March	6,000	6,000	0	7	31	0	43	72	43	43	43	88	89	89
Long Beach NRMC	5,280	5,280	2	2	90	15	15	92	22	22	94	96	96	98
USAFH, Nellis	3,900	3,417	0	12	21	0	36	50	37	37	37	80	80	80
Total/Average - Large Sites	54,998	50,729	9	8	42	46	58	76	30	23	55	74	59	89
Small Sites														
USAFH, Edwards	3,780	3,780	0	15	66	0	27	77	75	85	85	86	86	86
NAS, North Island	3,149	3,149	10	9	96	95	95	100	10	10	98	90	80	98
Naval Station, San Diego	3,148	2,712	10	80	93	100	100	100	13	96	96	80	80	96
USAFH, Vandenberg	2,808	2,808	8	8	30	47	47	80	42	42	42	84	84	84
USAFMF, Norton	2,280	2,426	0	22	34	0	40	64	58	57	57	75	75	75
Port Hueneme NRMC	1,699	1,313	0	13	68	0	68	73	5	18	72	92	86	94
USAFH, George	1,332	1,496	0	12	21	0	36	50	37	37	37	80	80	80
NTC Branch Clinic	1,302	1,679	0	24	89	0	31	100	100	98	92	98	86	95
NAB Coronado	1,200	1,307	0	68	74	50	99	99	2	76	76	98	68	93
Miramar NAS	1,320	1,320	0	70	82	0	99	99	100	86	86	100	71	94
29 Palms Branch Hospital	1,200	1,200	0	0	81	0	0	82	100	100	95	92	92	96
MCRD Branch Clinic	900	750	0	70	78	0	99	99	52	82	82	98	71	94
Barstow Branch Clinic	860	860	0	0	99	0	0	99	100	100	100	99	99	100
Total/Average - Small Sites	24,978	24,800	3	28	68	32	58	85	47	64	78	88	81	90
Regional Totals/Averages	79,976	75,529	7	15	51	42	58	79	35	37	63	78	67	89

*Percentage of ECGs meeting criteria.

X - Refers to X Period when manual ECG services were in use

Y - Refers to Y Period, one year following installation of CAPOC system

Full - Refers to projections of effectiveness when changes have been made which will result in achieving maximum benefits from CAPOC

TABLE 5- 3

SUMMARY OF ECG SERVICE DIRECT COSTS IN THE SOUTHERN CALIFORNIA AREA

		Annual Cost of Labor	Annual Cost of Supplies	Annual Cost of Maintenance and Repairs	Reading Costs	Equipment Costs	Annual Volume of ECGs
1.	San Diego NRMC	$91,874_{A}$	$15,866_{A}$	$22,000_{A}$	52,536	12,464	27,818
2.	Camp Pendleton	$58,540_{DA}$	$9,308_{A}$	$2,940_{A}$	25,680	5,539	12,000
3.	Nellis	$18,703_{DA}$	$4,620_{A}$	79_{DA}	6,924	692	3,900
4.	Miramar	$5,706_{A}$	792_{E}	109_{E}	1,740	1,731	1,320
5.	Twentynine Palms	$5,755_{DA}$	936_{E}	76_{E}	1,788	346	1,200
6.	Vandenberg	$13,698_{DA}$	$1,685_{A}$	76_{E}	5,040	346	2,808
7.	Edwards	$18,212_{E}$	$4,435_{E}$	378_{DA}	4,764	2,423	3,780
8.	George	$5,755_{DA}$	$1,571_{E}$	152_{E}	2,736	692	1,332
9.	Norton	$8,463_{E}$	860_{E}	71_{E}	3,180	823	2,280
10.	March	$29,266_{DA}$	$4,654_{E}$	337_{E}	11,184	2,034	6,000
11.	Long Beach	$23,436_{E}$	$4,096_{E}$	387_{DA}	8,856	6,578	5,280
12.	Naval Station	$10,156_{DA}$	$1,177_{E}$	$*_{A}$	6,216	173	3,148
13.	North Island	$8,463_{DA}$	$1,177_{E}$	$*_{A}$	6,216	173	3,149
14.	NTC	$5,078_{DA}$	391_{E}	$*_{A}$	1,872	1,558	1,302
15.	Coronado	$5,078_{DA}$	391_{E}	$*_{A}$	1,992	1,731	1,200
16.	MCRD	$3,047_{DA}$	271_{E}	$*_{A}$	1,248	1,731	900
17.	Port Hueneme	$7,007_{A}$	548_{A}	185_{DA}	3,426	2,077	1,699
18.	Barstow	$4,655_{E}$	671_{E}	109_{E}	1,296	1,731	860
	Total	322,892	53,449	26,899	146,694	42,842	79,976

KEY: A = Actual costs as obtained from facility
DA = Costs derived from actual data
E = Estimated costs from information obtained from similar facilities

FOOTNOTES: * Maintenance and repair costs already accounted for in San Diego NRMC's costs

5-4 through 5-7 summarize the various differential costs for the CAPOC system. The following section discusses each cost element.

As shown in Table 5-4, the time to read an ECG with the assistance of the unconfirmed computer interpretation was found to decrease with CAPOC. This conclusion is based on observations of cardiologists reading ECGs at San Diego NRMC during the X and Y Period data collection effort. The reduction in time was found to be 1.6 minutes/ECG over the manual system. The savings in reading costs are expected to occur primarily at the four largest sites in the area--San Diego NRMC, Camp Pendleton, March, and Long Beach. In addition, reading cost savings also occur for smaller sites who were having the ECGs read at a major site under the manual system. Savings in reading time in the entire region is estimated to affect 50,833 ECGs processed by CAPOC, or 67 percent of ECGs taken in the 18 MTFs.

The other aspect of labor savings is in technician time to perform various portions of the ECG process. Technician time is saved due to the elimination of such tasks as mounting of single-channel ECGs, typing the interpretation, matching tracings and interpretations, xeroxing interpretations and obtaining two ECG tracings (see Table 5-4). The average overall technician savings, measured by timed observations at San Diego NRMC, was found to be 3.6 minutes/ECG. This savings is only expected to affect the 41,312 ECGs taken at the three sites where ECG overreading services are provided--San Diego NRMC, Camp Pendleton and Long Beach. A reduction of 1.33 minutes/ECG is expected to occur at seven sites at which ECGs were previously mounted. A savings of 2 minutes/ECG will be realized at one site where interpretations were typed under the manual system.

The savings in supply costs occur due to the elimination of four elements:

- xeroxing ($0.5/copy)
- mounts for single-channel tracings ($0.15/mount)
- duplicate tracings -- one for the patient's medical record and one to be read ($0.04/tracing), and
- cover sheets ($0.06/sheet).

TABLE 5-4

COST SAVINGS FOR CAPOC ECG SERVICES AT FULL IMPLEMENTATION--YEAR 1

Cost Element	Number of Sites Affected	ECG Volume Affected	Savings* per ECG	Savings*
Reading Cost	6	50,833	$.784	$39,853
Technician Labor Costs				
Overall	3	41,312	$.422	$17,434
Mounting Tracing	7	14,311	$.156	$ 2,233
Typing Interpretation	1	1,313	$.235	$ 308
Supplies				
Xerox Copies	5	44,482	$.05	$ 2,224
Mounts	7	14,311	$.15	$ 2,147
Tracings	2	29,792	$.04	$ 1,192
Cover Sheets	1	14,059	$.06	$ 844
TOTAL Savings				$66,235

*1980 dollars.

TABLE 5-5

CAPOC SYSTEM COSTS

I.	Marquette Equipment and Services Contract		
	A. Initial Costs:		
	System Installation	$ 15,000	
	Training Classes	7,363	
	Training Materials	6,460	
	Software Conversion (includes share of initial conversion)	23,000	
	Software Modification: Storage and Retrieval	963	
	TOTAL		$ 52,786
	B. Maintenance/Software:		
	Software	$ 7,200/yr.	
	Central System (including plotter)	20,628/yr.	
	Overread Stations (Micromuse) 5 at $3,540/yr. =	17,700/yr.	
	User Site Printers 16 at $372/yr. =	5,952/yr.	
	Total Annual Cost for Maintenance and Software	$ 51,480/yr.	
	TOTAL Year 1 and Year 2 Maintenance and Software		$102,960
	C. Communication Costs:		
	Year 1 + 2 up to 7,000 ECGs/month		$108,864
	D. Equipment Lease (prior to 10/81):		
	Central Equipment (including plotter)	$ 63,564/yr.	
	Overread Stations--5 at $10,836 each	54,180/yr.	
	User Site Printers--16 at $1,140 each	18,240/yr.	
	Total Annual Lease Costs	135,984/yr.	
	TOTAL Lease Costs (Year 1 + Year 2)		$271,968

TABLE 5-5

CAPOC SYSTEM COSTS
(Continued)

E.	Equipment Purchase Price:		
	Initial		
	Central Equipment (including plotter)	$216,144	
	Overread Stations, 5 at $36,875 each	184,375	
	Printers, 16 at $3,870 each	61,920	
	TOTAL Equipment Purchase Price	$462,439	
F.	Equipment Buyout After Year 2:		
	Initial Cost-(.50 lease payments Year 1 + .55 lease payments Year 2) = $462,439 - ($67,992 + $74,791)		$319,656
G.	Recurring Costs Years 3-8:		
	Yearly Maintenance/Software Base Cost $51,480/yr Inflated at 10% per year		
	Year 3	$ 56,628	
	Year 4	62,291	
	Year 5	68,520	
	Year 6	75,372	
	Year 7	82,909	
	Year 8	91,200	
	TOTAL Maintenance Years 3-8		$436,920
	Yearly Communications Costs $54,432/yr Inflated at 10% per year		
	Year 3	$ 59,875	
	Year 4	65,863	
	Year 5	72,449	
	Year 6	79,694	
	Year 7	87,663	
	Year 8	96,430	
	TOTAL Communications Years 3-8		$461,974

TABLE 5-6

SITE COSTS FOR CAPOC SYSTEM AT FULL IMPLEMENTATION

Equipment Purchase	
Carts	
Initial Purchase of 7 Carts	$ 67,328
Modification of 4 Carts to Transmit to CAPOC at $3,000 each	12,000
One Additional Cart on Order	11,000
Recommended Additional Purchases:	
2 Carts at $11,000 each	22,000
1 Printer at $3,870	3,870
TOTAL	116,198
Average Annual Cost*	22,949
Supply Costs	
Paper	
For Overread Stations ($29/3000 sheets)	1,894
Printers at site ($25.37/4,000 sheets)	145
Purchase of Floppy Discs and Replacement of System Discs as needed	2,000
TOTAL	4,039

*Based on a 5-year lifetime for carts and an 8-year lifetime for printers.

TABLE 5-7

SUMMARY OF DIFFERENTIAL COSTS FOR CAPOC ECG SERVICES

SAVINGS		$/Year
Reading		39,853
Labor		19,975
Supplies		6,407
TOTAL		66,235
COSTS		
System		
Initial Costs	$ 52,786	
Maintenance, Software Year 1 and Year 2	102,960	
Communications Year 1 and Year 2	108,864	
Equipment Lease Year 1 and Year 2	271,968	
Equipment Buyout	319,656	
Maintenance Totals Years 3-8	436,920	
Communications Total Years 3-8	461,974	
Annual Cost for an 8-Year Lifetime		219,391
Site		
Equipment		22,949
Supplies		4,039
TOTAL		246,379
Net Differential Cost of CAPOC		$180,144

* Based on an 8 year lifetime.

These savings are specific for each site and depend on the ECG process that existed in the manual system and the changes that have occurred as a result of CAPOC.

Cost increases due to CAPOC are incurred on a regional basis and at the individual sites. The regional cost, summarized in Table 5-5, is the cost to lease the system for two years and then purchase it. After the purchase, there are yearly costs for maintenance, software and communications. The contract specifies that these will be escalated at 10% annually. The total regional cost for CAPOC over its 8-year lifetime is $1,755,131, or $219,391 annually.

The site costs include the purchase of equipment and supplies for use with CAPOC. Seven three-channel transmitting ECG carts were purchased. One additional cart is on order and two more carts are recommended to increase capture of ECGs by CAPOC and an old cart at one site needs to be replaced. Also, one additional printer is recommended to increase access to CAPOC. The cost of this additional equipment has been included in the Y Period differential cost. Initially four sites upgraded their ECG carts in order to transmit to CAPOC. The annual yearly cost, assuming a five-year lifetime for the ECG carts and an 8 year lifetime for the printers, is $22,949.

Supply costs consist of paper for the overread stations, paper for the printer and discs for the computer. Overread paper is used at a rate of 4 sheets/ECG processed at the overread site itself and 2 sheets/ECG overread for smaller sites. Printer paper is estimated to be one-half sheet per report. If an ECG has both an unconfirmed and confirmed report, the total amount used is one sheet per ECG. Differential supply costs are $4,039 in the base year and will inflate at 10% annually over the lifetime of the CAPOC system.

The differential costs and savings attributable to CAPOC are summarized in Table 5-7. The additional costs are $246,379 per year. These are offset by savings of $66,235 per year for a total differential cost of $180,144 per year. This represents $2.39 per ECG taken in the Y Period.

A life-cycle cost analysis was performed using the costs and savings discussed. The summary of the analysis is presented in Table 5-8. The total discounted annual cost of the CAPOC system is $116,631 or an increase of $1.54 per ECG processed in the Y Period.

C. COST-EFFECTIVENESS OF THE CAPOC SYSTEM

The costs of manual and CAPOC services when combined with service effectiveness yield the cost-effectiveness of ECG services in the two periods for the Southern California area, and large and small MTFs. In addition to evaluating the actual cost-effectiveness at the two service levels, a cost-effectiveness is calculated based on annual ECG volumes of 75,000 and 100,000. The cost-effectiveness for each period and under the two varying volumes is given in Table 5-9.

In the X Period, the cost of ECG services was $592,776. Of the 79,976 ECGs taken, 50.3 percent or 40,282 ECGs met the criteria for effective service. Thus the cost per effective ECG with manual services was $14.72. The cost per preferred ECG (5,539 ECGs in the X Period) was $107.02.

In order to calculate the total cost for CAPOC services, the X Period costs were adjusted for the new volume of 75,529 ECGs. If 75,529 ECGs were done with the manual system, the total cost would have been $563,700. The total cost for CAPOC services is this amount plus the average annual lifecycle cost for CAPOC of $116,631 or $680,331 in total. The total number of effective ECGs is projected to be 59,171 when CAPOC is fully implemented. Thus the cost per effective ECG with CAPOC services will drop to $11.50. The cost per preferred ECG (38,299 ECGs) will decline to $17.76. The change in cost per effective ECG is more dramatic in the small MTFs than in the large ones.

In order to have a comparable basis for comparison, the costs for manual and CAPOC ECG services were calculated based on annual volumes of 75,000 and 100,000 ECGs. This calculation presents the overall effect of fixed and variable costs on the cost-effectiveness. The cost per effective ECG decreases with increasing volume. However, the difference between costs under the two systems also becomes smaller.

TABLE 5-8

ANNUAL AND DIFFERENTIAL LIFE-CYCLE COST OF THE CAPOC SYSTEM
IN 18 MTFs IN THE SOUTHERN CALIFORNIA AREA

	YEAR							
	1	2	3	4	5	6	7	8
Costs								
Initial Costs	52,786							
Equipment Lease	135,984	135,984						
Equipment Purchase			319,656					
Maintenance/Software	51,480	51,480	56,628	62,291	68,520	75,372	82,909	91,200
Communication	54,432	54,432	59,875	65,863	72,449	79,694	87,663	96,430
Total System	294,682	241,896	436,159	128,154	140,969	155,066	170,572	187,630
Cart Purchase	79,328		36,870					
Paper Costs	4,039	4,443	4,887	5,376	5,914	6,505	7,155	7,871
Total All Expenses	378,049	246,339	477,916	133,529	146,882	161,571	177,728	195,500
Discounted at 10 Percent	360,659	213,576	376,598	95,741	95,767	95,650	95,617	95,600
Savings								
Supplies	6,407	7,048	7,752	8,528	9,380	10,319	11,350	12,485
Labor	59,828	66,828	72,909	79,471	86,226	93,124	100,108	107,617
Total Savings	66,235	73,876	80,662	87,999	95,607	103,443	111,459	120,102
Discounted at 10 Percent	63,188	64,050	63,561	63,095	62,335	61,238	59,965	58,730
Total Costs	933,044							
Costs Per Year	116,631							

TABLE 5-9

COST-EFFECTIVENESS OF MANUAL AND CAPOC ECG SERVICES UNDER DIFFERENT VOLUMES

	Total Costs ($/Year)	ECG Costs ($/ECG)	
		Effective	Preferred
Manual Services			
X Period			
Southern California Area - 79,926 ECGs	592,776	14.72	107.02
Large MTFs - 54,998 ECGs	418,593	13.59	84.57
Small MTFs - 24,978 ECGs	174,183	18.35	232.45
75,000 ECGs per year	560,241	14.85	108.26
100,000 ECGs per year	723,741	11.14	104.89
CAPOC Services			
Full Implementation			
Southern California Area - 75,529 ECGs	680,331	11.50	17.76
Large MTFs - 50,729 ECGs	478,687	12.58	22.47
Small MTFs - 24,800 ECGs	201,644	11.96	9.45
75,000 ECGs per year	677,279	11.53	17.81
100,000 ECGs per year	825,623	10.54	16.28

D. QUALITATIVE RESULTS

The staff questionnaire and interviews conducted during site visits complemented and, in some cases, extended the quantitative assessment of the impacts of CAPOC in the 18 MTFs. The largest number of questionnaires was returned by physicians, nurses, and corpsmen at San Diego NRMC (70 in the X Period and 107 in the Y Period). Seventy-seven of the respondents to the Y Period survey had experienced the previous manual ECG process and participated in the implementation period. Furthermore, San Diego NRMC is the largest overreading site in the CAPOC network, and 30 physician respondents in the Y Period were performing ECG reading functions (interpreting ECGs for patients treated by others or checking interpretations by others). San Diego NRMC was the first site to be using CAPOC and thus had had a year of experience with CAPOC services when Y Period surveys were conducted. Therefore, the experience and opinions of staff at San Diego NRMC were the most comprehensive qualitative information available on the impacts of automation on the overall ECG process. The following discussion of qualitative results focuses on information obtained at San Diego NRMC and incorporates information from the other sites as available and appropriate.

When asked about the aspects of ECG services most important to the use of the ECG in patient care, physicians consistently gave the highest ratings to turnaround times (especially for STAT ECGs); accuracy, completeness, and consistency of ECG readings; and availability of prior tracings for serial comparison. When asked about turnaround times for interpreted ECGs, most physicians believed that a STAT ECG was needed within 30 minutes and a routine ECG was needed within 24 hours. Thus, the questionnaire results tend to affirm the validity of the measures used to evaluate service quality and generally confirm the quantitative results regarding service effectiveness at San Diego NRMC.

Physicians also rated quality of tracings and legibility of results as very important. At San Diego NRMC, satisfaction ratings for turnaround times for tracings and interpretations, technical quality of tracings, and ease of reading and understanding interpretations, all improved after automation. (A decline was reported in service quality

for serial comparisons. This is not surprising since automated storage and retrieval of ECGs was not available in the Y Period and manual files were not being maintained.) Overall declines were noted in reported satisfaction with accuracy, completeness, and consistency of ECG interpretations during the Y Period. This is not consistent with responses to questions regarding changes in services resulting from CAPOC. Of those physicians who believed they had sufficient exposure to CAPOC to comment, 33 percent cited improved accuracy and 50 percent reported that interpretations were more complete with CAPOC. Large numbers of those who commented cited improvements in technical quality of tracings (57 percent) and ease of reading and understanding interpretations.

Physicians at all sites reported that their role in delivery of ECG services was not changed by CAPOC. However, San Diego physicians reported decreased time devoted to reading: an average of 1.5 minutes per normal ECG vs. 1.3 minutes with CAPOC and 3.9 minutes per abnormal ECG vs. 3.1 minutes with CAPOC.

ECG readers, who interpret the largest volumes of ECGs (average of 15 per week with 12 reading more than 25) were more likely to report time savings (34 percent vs. 6 percent). Physicians spending less time cited computer measurements of intervals and rate, legibility of the CAPOC report, and less time for writing and interpretation. Some of those who reported no time savings mentioned the lack of a computer interpretation in time to be useful (this is consistent with measured turnaround times for the Y Period) or the need to check ECGs anyway.

In the quantitative evaluation of ECG service effectiveness, the specialized training of the ECG reader was used as the means of measuring changes in reading quality. This was complemented by the portion of the staff questionnaire concerning the relative accuracy of manual and computer-assisted interpretations. The opinions of 70 physicians at San Diego NRMC were used as the basis for assessing this aspect of ECG services because they read the highest ECG volumes and had the most experience with CAPOC. Of 29 physician respondents in the Y Period who performed ECG reading functions, 23 believed CAPOC readings were at least as accurate as manual readings overall, and only 6 believed CAPOC was less

accurate overall. Only one of 45 respondents believed that manual reading was more accurate for normal ECGs. For abnormal ECGs, 28 respondents believed CAPOC was at least as accurate vs. 16 who believed manual reading was more accurate. Generally, these physicians believed that CAPOC was more accurate in identifying ST-T wave abnormalities, hypertrophy, and conduction abnormalities than in detecting rhythm abnormalities and myocardial infarctions. Most of the physician readers (24 of 34 who responded) felt that computer errors tended to be false-positive errors (calling a normal ECG abnormal) rather than false-negative errors.

Other impacts of CAPOC reported by questionnaire respondents included fewer lost or inadequate tracings. Some physicians believed that this had led to fewer patient recalls for repeat ECGs.

When asked about overall satisfaction with CAPOC, 68 physicians at San Diego NRMC were satisfied with the system, versus 10 who were unsatisfied. Thus, physician acceptance appears to be high despite the longer than anticipated implementation period. Specific comments about problem areas indicate that some of the dissatisfaction may be attributed to operational or technical problems rather than basic capabilities of the CAPOC system. Several physicians noted that CAPOC should be more available in primary care areas and/or that there was insufficient or outdated equipment in areas of high patient concentrations. Numerous commentors also cited the unavailability of unconfirmed interpretations and the delay before the confirmed interpretations reach patient charts.

E. SENSITIVITY ANALYSIS

In order to test the sensitivity of the conclusions about the cost effectiveness of CAPOC to key variables and assumptions, several cases were identified and evaluated:

Case 1: the use of corpsmen to confirm normal CAPOC interpretations, thus relieving physicians of overreading this set of ECGs,

Case 2: exclusion of the ECGs taken in the intensive care units at San Diego NRMC from the analysis because

the process for reading the ECGs is different from the process for the rest of the ECG volume,

Case 3: consideration of the ECGs from the intensive care units at San Diego NRMC as automatically meeting criteria for effective turnaround time and reader because they are read immediately by the requesting physician and the staff in these units have training in cardiology, and

Case 4: inclusion of a fixed rate of overhead cost in all 18 MTFs for different volumes of ECGs.

The results of these sensitivity analyses, contrasted with the cost effectiveness conclusions from the original analysis, are summarized in Table 5-10 and in the following discussion. (Note that the sensitivity of results to assumptions about the volume processed were examined previously in Section B of this chapter.)

According to the evaluation criteria used to evaluate service effectiveness changes resulting from CAPOC, a corpsman becomes an effective reader of ECGs for normal tracings with the assistance of the computer-generated interpretation. Case 1 assumes that this is adopted as standard practice either at all sites or at only the major sites. Table 5-10 indicates that this increases the cost effectiveness of CAPOC. The change is due to the reduction in labor costs for confirming normal ECGs and a 1.6-minute physician time saving for reading abnormal ECGs.

ECGs taken in intensive care units serve a different purpose than other routine ECGs and the process for taking and reading them differs as well. These ECGs are used to monitor the progress of patients with known or suspected myocardial infarctions or other cardiac abnormalities. At San Diego NRMC they are usually read in the unit in which they are taken before being sent to the Heart Station for a formal reading. At San Diego, these ECGs accounted for 18 percent of the X Period volume and 11 percent of the Y Period volume. If the reading by the Heart Station was counted as the official reading for purposes of the evaluation, many of these ECGs did not meet criteria for effective turnaround time. Therefore, two sets of different assumptions were examined with regard

TABLE 5-10

RESULTS OF SENSITIVITY ANALYSIS OF THE EFFECT OF KEY ASSUMPTIONS ON THE CONCLUSIONS REGARDING THE COST EFFECTIVENESS OF CAPOC

Assumptions	Key Variable(s)	Cost Effectiveness of ECG Services			
		Cost per Effective ECG		Cost per Preferred ECG	
		X Period	Full Imp.	X Period	Full Imp.
Original set of assumptions	--	$14.72	$11.50	$107.02	$17.76
Case 1: Corpsmen are effective readers with CAPOC and confirm normal ECGs	Reduced labor cost for reading normal ECGs and reduced time for reading abnormal ECGs				
• All sites		not applicable	$10.94	not applicable	$16.90
• Major sites		not applicable	$11.21	not applicable	$17.32
Case 2: Exclude ICU ECGs at San Diego NRMC	Reduced volume of ECGs (18% in X Period, 11% in Y Period)	$13.61	$11.70	$144.24	$18.11
Case 3: Count ICU ECGs at San Diego NRMC as effective ECGs	Increase in number meeting criteria for effective and preferred turnaround time and reader	$14.02	$11.22	$ 66.44	$16.98
Case 4: Include overhead cost at rate reported for Camp Pendleton	Addition of 16% to costs of ECG services				
• Original volumes used in analysis	79,926 ECGs per year (X), 75,526 ECGs per year (Full)	$17.07	$13.34	$124.14	$20.61
• 75,000 ECGs per year		$17.23	$13.37	$125.58	$20.66
• 100,000 ECGs per year		$12.92	$12.23	$121.67	$18.88

to these ECGs. Case 2 assumes that these ECGs should be excluded from consideration; variable costs of ECG services were assumed to be reduced by the same percentage as the reduction in volume. Case 3 assumes that the official reading occurs in the intensive care unit and the entire volume meets all criteria for preferred service. As shown in Table 5-10, both of these cases demonstrate increased cost effectiveness of CAPOC.

In the X Period, Camp Pendleton was the only CAPOC site at which the Uniform Chart of Accounts had been implemented. Therefore, this was the only site for which data were available on the overhead costs of providing ECG services in a MTF. Because there was no basis for assigning this overhead rate to the other sites, overhead costs were excluded in the original cost analysis. In order to test the sensitivity of the results to the inclusion of overhead costs, the 16% overhead rate from Camp Pendleton was applied to all of the sites. As shown in Table 5-10, the result of this change is to increase the per ECG costs and the difference in costs between manual and automated services.

The sensitivity analysis indicates that volume is the single most critical factor determining the cost effectiveness of automated services. It also verifies that the original assumptions used were conservative, since all of the other assumptions tested show CAPOC to be even more cost effective.

APPENDIX A

STAFF QUESTIONNAIRES FOR PRIMARY EVALUATION SITES

For Computer Use Only:

Resp. I.D. _____
(Col. 1 - 4)

Base: 5 - 1 2 3 4 5
Clinic: 6 - 1 2 3 4 5
Date: 7 - (1) 2 3

STUDY OF ECG SERVICES

Wave 1

Please be assured that we wish this study to be absolutely anonymous. We can understand opinions best when combining a person's answers to the first questionnaire with his/her answers to the second and third questionnaires. Since we don't want you to write down your name, we have chosen your date of birth as an identifier to appear on all your questionnaires.

For example: a person born on January 6, 1940, will have an identification #010640. We have chosen your date of birth because it is a number which will not change and no attempt will be made to link this information with your name.

Please write your identifier here: _____
(Identifier)

This questionnaire is designed to be keypunched; for this purpose please indicate your answers by circling code numbers instead of writing the customary check marks. For example:

Are you here to have an ECG taken? *(circle code number)* Yes (14-1) No -2

* * *

1. Which of the following functions, if any, do you perform related to ECGs? *(Circle as many as apply)*

Order ECGs to be taken on patients	17-1
Interpret ECGs for my own patients	-2
Interpret ECGS for patients being treated by others	-3
Check ECG interpretations done by others	-4
Take ECGs	-5
File ECGs	-6
Schedule patients for ECGs	-7
Manage the ECG department	-8
Other *(specify)* _____	-9
Do not perform any functions related to ECGs	-0

2. To your knowledge, are patients ever recalled to have a repeat ECG taken because the technical quality of the tracing was inadequate for interpretation?

Yes	18-1
No	-2
Don't know	-3

3. How often would you say these recalls occur due to inadequate ECG quality?

Often	19-1
Seldom	-2
Hardly ever	-3
Never	-4
Don't know	-5

4. To your knowledge, are patients ever recalled to have a repeat ECG taken because their ECG has been lost?

Yes	20-1
No	-2
Don't know	-3

5. How often would you say these recalls occur due to the loss of an ECG?

Often	21-1
Seldom	-2
Hardly ever	-3
Never	-4
Don't know	-5

6. To your knowledge, are patients ever referred to other medical facilities (off base) for cardiology consults?

Yes	22-1
No	-2
Don't know	-3

7. How often, would you say, these referrals off base occur?

Often	23-1
Seldom	-2
Hardly ever	-3
Never	-4
Don't know	-5

8. What are some of the reasons why patients are referred off base for cardiology consults?

_____ 24

_____ 25

9. For each of the following types of locations where ECGs are taken, what is an acceptable delay between the request for a STAT ECG and the time it is taken?

a. in the emergency room *(circle one)*

0-15 minutes	*69-1*
16-30 minutes	*-2*
31-45 minutes	*-3*
46-60 minutes	*-4*
over 60 minutes	*-5*

b. in other medical treatment areas *(circle one)*

0-15 minutes	*70-1*
16-30 minutes	*-2*
31-45 minutes	*-3*
46-60 minutes	*-4*
over 60 minutes	*-5*

10. What is an acceptable delay between the request for a routine ECG and the time it is taken? *(circle one)*

less than 1 hour	*71-1*
1-4 hours	*-2*
5-8 hours	*-3*
9-24 hours	*-4*
over 24 hours	*-5*

11. Ideally, how long on the average do you think it should take from the time a STAT ECG is ordered to the time the interpretation is available? (Write in the amount of time--minutes or hours--in the box.)

Amount of time ---------- [ ] *72- 73- 74- 75-*

12. Ideally, how long on the average do you think it should take from the time a routine ECG is ordered to the time the interpretation is available? (Write in the amount of time--minutes, hours, or days--in the box.)

Amount of time ---------- [ ] *76- 77- 78- 79-*

END OF CARD *80* - (1)

13. Listed below are attributes an ECG service can provide. Using a scale from *1* to *5*, please assign a rating to each attribute to indicate how important that service is to you (e.g., a rating of *1* means this is very important to you and a rating of *5* means this service is very unimportant to you). You can choose any number between *1* and *5* and please circle one number for each line.

For example: If it is very important to you that STAT ECGs can be taken 24 hours a day, circle *26*-①. If this is very unimportant to you, circle *26*-⑤. And if this item strikes you as being somewhere in between very important, circle *26*-② or *26*-③ or *26*-④—only one circle for each item.

		Very Important				Very Unimportant
a.	STAT ECGs can be taken 24 hours a day	*16*-1	-2	-3	-4	-5
b.	Routine ECGs can be taken 24 hours a day	*17*-1	-2	-3	-4	-5
c.	STAT ECG interpretations are available 24 hours a day	*18*-1	-2	-3	-4	-5
d.	Routine ECG interpretations are available 24 hours a day	*19*-1	-2	-3	-4	-5
e.	ECGs can be taken in all diagnostic and treatment areas	*20*-1	-2	-3	-4	-5
f.	ECGs can be interpreted in all diagnostic and treatment areas	*21*-1	-2	-3	-4	-5
g.	Interval between the time of a request for a STAT ECG and the time it is taken is within acceptable limits*	*22*-1	-2	-3	-4	-5
h.	Interval between the time of a request for a routine ECG and the time it is taken is within acceptable limits*	*23*-1	-2	-3	-4	-5
i.	Interval between the time of a request for a STAT ECG and the time the interpretation is available is within acceptable limits*	*24*-1	-2	-3	-4	-5
j.	Interval between the time of a request for a routine ECG and the time the interpretation is available is within acceptable limits*	*25*-1	-2	-3	-4	-5
k.	ECG interpretations are accurate	*26*-1	-2	-3	-4	-5
l.	ECG interpretations are complete (all aspects noted)	*27*-1	-2	-3	-4	-5
m.	ECG tracings are of high technical quality	*28*-1	-2	-3	-4	-5
n.	Different readers make the same readings	*29*-1	-2	-3	-4	-5
o.	Interpretations are easy to read and understand	*30*-1	-2	-3	-4	-5
p.	Prior ECG tracings are available for comparison purposes	*31*-1	-2	-3	-4	-5
q.	Experts (cardiologists or other ECG specialists) are available to discuss significance of ECG interpretation in patient management	*32*-1	-2	-3	-4	-5
r.	Other *(specify)* _____	*33*-1	-2	-3	-4	-5

* As defined by you in Questions 9-12.

E. These attributes are listed once more. This time please indicate how satisfied you are with these attributes as provided by the current ECG system here (e.g., a rating of *1* means always satisfactory and a rating of *5* means never satisfactory). You can choose any number between *1* and *5* to indicate how satisfied you are. Please circle one code for each line.

	Very Satisfied				Very Unsatisfied	Not Applicable or Don't Know
a. Number of hours a day STAT ECGs can be taken	*34-1*	-2	-3	-4	-5	-6
b. Number of hours a day routine ECGs can be taken	*35-1*	-2	-3	-4	-5	-6
c. Number of hours a day STAT ECG interpretations are available	*36-1*	-2	-3	-4	-5	-6
d. Number of hours a day routine ECG interpretations are available	*37-1*	-2	-3	-4	-5	-6
e. Number of diagnostic and treatment areas where ECGs can be taken	*38-1*	-2	-3	-4	-5	-6
f. Number of diagnostic and treatment areas where ECGs can be interpreted	*39-1*	-2	-3	-4	-5	-6
g. Interval between the time of a request for STAT ECG and the time it is taken	*40-1*	-2	-3	-4	-5	-6
h. Interval between the time of a request for a routine ECG and the time it is taken	*41-1*	-2	-3	-4	-5	-6
i. Interval between the time of a request for a STAT ECG and the time the interpretation is available	*42-1*	-2	-3	-4	-5	-6
j. Interval between the time of a request for a routine ECG and the time the interpretation is available	*43-1*	-2	-3	-4	-5	-6
k. Accuracy of ECG interpretations	*44-1*	-2	-3	-4	-5	-6
l. Completeness (all aspects noted) of ECG interpretations	*45-1*	-2	-3	-4	-5	-6
m. Technical quality of ECG tracings	*46-1*	-2	-3	-4	-5	-6
n. Consistency of interpretations made by different readers	*47-1*	-2	-3	-4	-5	-6
o. Ease of reading and understanding interpretations	*48-1*	-2	-3	-4	-5	-6
p. Availability of prior ECG tracings for comparison purposes	*49-1*	-2	-3	-4	-5	-5
q. Availability of experts (cardiologists or other ECG specialists) to discuss significance of ECG interpretation in patient management	*50-1*	-2	-3	-4	-5	-6
r. Other *(specify)* _____	*51-1*	-2	-3	-4	-5	-6

END OF CARD *80* - (2)

15. Do you personally read/interpret ECGs or overread ECGs (i.e., check the interpretation made by someone else)? *(Circle as many as apply)*

	Read/interpret ECGs----------	23-1
	Overread ECGs ----------	-2
Skip to Q. 20 ←	Do not do either ----------	-3
Skip to Q. 20 ←	Don't know ----------	-4

Answer Q. 16-19 only if you read/interpret or overread ECGs.

---

16. How many ECGs do you estimate you read in an average week? *(Write in the number of ECGs in the box at the right)*

Number of ECGs ------ [ ] 24-25-26-27-

17. How much time would you say it takes you on the average to make the following types of ECG interpretations? Please write in an answer for each line. If you don't interpret this type, circle the column on the right.

	Minutes	Seconds	Don't Interpret	
a. Interpretation of a single ECG that is within normal limits ----------	#	#	28-1	30-31-32-33-
b. Interpretation of an abnormal ECG ---	#	#	29-1	34-35-36-37-
c. Serial comparison with a prior ECG tracing ----------	#	#	30-1	38-39-40-41-
d. Other interpretation _____ *(specify)*	#	#	31-1	42-43-44-45-

18. If you overread ECG interpretations made by others how many do you overread in an average week? *(Write in the number of ECGs in the box).*

Number of ECGs ------ [ ] 46-47-48-49-

19. How much time do you spend overreading in an average week? *(Write in the amount of time in the box)*

Amount of time ------ [ ] 50-51-52-53-

Finally, for background purposes only, please answer the following questions.

20. What is your professional specialty?

Staff physician (Specialty) _____ -----	26-1
House staff officer (intern, resident or fellow) ----------	-2
Nurse ----------	-3
Corpsman or technician ----------	-4
Other *(specify)* _____ -----	-5

21. How long have you been working in your current job at this facility?

Less than six months ----------	27-1
6 - 12 months ----------	-2
13 months or longer ----------	-3
Don't know ----------	-4

22. What is your military status?

Active duty military ----------	28-1
Civilian ----------	-2
Other *(specify)* _____ --	-3
Don't know ----------	-4

23. Please write in any comments you may have concerning the ECG system at your base.

_____ 29-

_____ 30-

Thank you for your time and effort. Please return this questionnaire in the attached prepaid self-addressed envelope.

Card Number 80-2

STUDY OF ECG SERVICES

Wave 2

In November 1979 a computer system called CAPOC was installed to provide computer-assisted reading to electrocardiograms (ECGs) at USAF Hospital, Nellis Air Force Base. This Questionnaire is designed to record your experience with the CAPOC system, and your views of changes that have occurred in ECG services at Nellis, since CAPOC was installed.

We would like all staff to answer questions about the requirements for ECG services and satisfaction with current CAPOC services.

If you worked here before CAPOC was installed, we will ask you to answer some additional questions about changes in services.

Please be assured that we wish your responses to be anonymous. For those staff who were here prior to CAPOC installation, we would like to compare responses to this questionnaire with responses given in the first survey distributed a year ago. We have chosen your date of birth as an identifier to appear on all your questionnaires.

For example: a person born on January 6, 1940, will have an identification #010640. We have chosen your date of birth because it is a number which will not change. No attempt will be made to link this information with your name.

Please write your identifier here

_____ _____ _____

Month Day Year

For Computer Use Only
Cols. (3-8)
Bases 9-1 2 (3) 4 5
Wave 10 (2)

This questionnaire is designed to be keypunched; for this purpose please indicate your answers by circling the code numbers (e.g., 14(1)) instead of writing the customary check marks.

Example:

Do your order ECGs to be taken on your patients?	Yes	14(1)
	No	-2

1. What functions, if any, do you perform related to ECGs? *(Check as many as apply.)*

a. Order ECGs to be taken on patients----------11-1
b. Interpret ECGs for my own patients---------- -2
c. Interpret ECGs for patients being treated by others---------- -3
d. Check ECG interpretations done by others---------- -4
e. Take ECGs---------- -5
f. File ECGs---------- -6
g. Schedule patients for ECGs---------- -7
h. Manage the ECG department---------- -8
i. Other (specify)_____---------- -9
j. Do not perform any functions related to ECGs---------- -0

1a. Were you on the staff at Nellis before October 1979 when the CAPOC computer-assisted ECG system was installed?

Yes----------12-1
Skip to Q. 3 | No---------- -2
Skip to Q. 3 | Don't know---------- -3

If you were on the staff of Nellis Air Force Base prior to November 1979 and have experience with both the manual and computerized ECG services, please answer question 1b. If not, proceed to question 2.

1b. If the functions you perform now differ from those you performed before CAPOC was installed, please write in what these functions are and how they differ from what you used to do before CAPOC installation.

_____13-

_____14-

_____

2. To your knowledge, using the CAPOC system, are patients ever recalled to have a repeat ECG taken because the technical quality of the tracing is inadequate for interpretation?

Yes----------15-1
No---------- -2
Don't know---------- -3

3. How often would you say these recalls occur due to inadequate ECG quality?

Often----------16-1
Seldom---------- -2
Hardly Ever---------- -3
Never---------- -4
Don't know---------- -5

4. To your knowledge, using the CAPOC system, are patients ever recalled to have a repeat ECG taken because their ECG has been lost?

Yes	17-1
No	-2
Don't know	-3

5. How often would you say these recalls occur due to the loss of an ECG?

Often	18-1
Seldom	-2
Hardly Ever	-3
Never	-4
Don't know	-5

If you were on the staff of Nellis Air Force Base prior to November 1979, and have experience with both manual and computerized ECG services please answer questions 5a. and 5b. If not, please proceed to question 5c.

5a. When comparing CAPOC with manual ECG services would you say repeat ECGs taken because of poor technical quality occur:

More often since CAPOC	19-1
Less often since CAPOC	-2
About as often as before	-3

5b. When comparing CAPOC with manual ECG services would you say ECGs are lost:

More often since CAPOC	20-1
Less often since CAPOC	-2
About as often as before	-3

5c. To your knowledge, since CAPOC has been available, are ECGs ever taken and interpreted manually and not transmitted to the computer system?

Yes	21-1
No	-2
Don't know	-3

5d. What are some of the reasons, if any, why a manual system is used instead of CAPOC? (*Check as many as apply.*)

a.	CAPOC system is not available in all areas where ECGs are taken	22-1
b.	CAPOC system is not available at all times (e.g., not available nights or weekends)	-2
c.	CAPOC system is busy	-3
d.	CAPOC system is not working	-4
e.	Manual system is more satisfactory	-5
f.	Other (Specify) _____	-6
g.	Don't know	-7

5e. If you indicated that a manual system is more satisfactory, please write in why you say so.

_____ 23-

_____ 24-

_____

5f. How frequently would you say, ECGs are taken manually and not transmitted to the computer system?

Almost every day----------25-1
About once a week---------- -2
About once a month---------- -3
Less than once a month---------- -4
Never---------- -5
Don't know---------- -6

6. To your knowledge, using the CAPOC system, are patients ever referred to other medical facilities for cardiology consults?

Yes----------26-1
No---------- -2
Don't know---------- -3

7. How often, would you say, these referrals off base occur?

Often----------27-1
Seldom---------- -2
Hardly Ever---------- -3
Never---------- -4
Don't know---------- -5

8. What are some of the reaons why patients are currently referred off base for cardiology consults? *(Please write in.)*

_____ 28-

_____ 29-

_____

If you were on the staff of Nellis prior to installation of CAPOC please answer question 8a. If not proceed to question 9.

8a. Compared with the time before CAPOC was installed do you feel the frequency of off base referrals has increased, decreased or has it stayed the same?

Increased----------30-1
Decreased---------- -2
Stayed the same---------- -3
Don't know---------- -4

9. For each of the following types of locations where ECGs are taken, what is an acceptable delay between the request for a STAT ECG and the time it is taken?

a. In the emergency room (*circle one*)

0-15 minutes	31-1
16-30 minutes	-2
31-45 minutes	-3
46-60 minutes	-4
over 60 minutes	-5

b. In other medical treatment areas (*circle one*)

0-15 minutes	32-1
16-30 minutes	-2
31-45 minutes	-3
46-60 minutes	-4
over 60 minutes	-5

10. What is an acceptable delay between the request for a routine ECG and the time it is taken? (*circle one*)

less than 1 hour	33-1
1-4 hours	-2
5-8 hours	-3
9-24 hours	-4
over 24 hours	-5

11. Ideally, how long on the average do you think it should take from the time a STAT ECG is ordered to the time the interpretation is available? (*Write in the amount of time and indicate minutes or hours in the box.*)

Amount of time---------[ ] (34 - 37)

12. Ideally, how long on the average do you think it should take from the time a routine ECG is ordered to the time the interpretation is available? (*Write in the amount of time--minutes, hours, or days--in the box.*)

Amount of time---------[ ] (38 - 41)

13. Listed below are attributes an ECG service can provide. Using a scale from 1 to 5, please assign a rating to each attribute to indicate how important that service is to you (e.g., a rating of 1 means this is very important to you and a rating of 5 means this service is very unimportant to you). You can choose any number between 1 and 5 and please circle one number for each line.

For example: If it is very important to you that STAT ECGs can be taken 24 hours a day, circle 42-(1). If this is very unimportant to you, circle 42-(5). And if this item strikes you as being somewhere in between very important and very unimportant, circle 42-(2) or 42-(3) or 42-(4)--only one circle for each item.

	Very Important				Very Unimportant
a. STAT ECGs can be taken 24 hours a day	42-1	-2	-3	-4	-5
b. Routine ECGs can be taken 24 hours a day	43-1	-2	-3	-4	-5
c. STAT ECG interpretations are available 24 hours a day	44-1	-2	-3	-4	-5
d. Routine ECG interpretations are available 24 hours a day	45-1	-2	-3	-4	-5
e. ECGs can be taken in all diagnostic and treatment areas	46-1	-2	-3	-4	-5
f. ECGs can be interpreted in all diagnostic and treatment areas	47-1	-2	-3	-4	-5
g. Interval between the time of a request for a STAT ECG and time it is taken is within acceptable limits*	48-1	-2	-3	-4	-5
h. Interval between the time of a request for routine ECG and the time it is taken is within acceptable limits	49-1	-2	-3	-4	-5
i. Interval between the time of a request for a STAT ECG and the time the interpretation is available is within acceptable limits*	50-1	-2	-3	-4	-5
j. Interval between the time of a request for a routine ECG and the time the interpretation is available is within acceptable limits*	51-1	-2	-3	-4	-5
k. ECG interpretations are accurate	52-1	-2	-3	-4	-5
l. ECG interpretations are complete (all aspects noted)	53-1	-2	-3	-4	-5
m. ECG tracings are of high technical quality	54-1	-2	-3	-4	-5
n. Different readers make the same readings	55-1	-2	-3	-4	-5
o. Interpretations are easy to read and understand	56-1	-2	-3	-4	-5
p. Prior ECG tracings are available for comparison purposes	57-1	-2	-3	-4	-5
q. Experts (cardiologists or other ECG specialists) are available to discuss significance of ECG interpretation in patient management	58-1	-2	-3	-4	-5
r. Other (specify) _____	59-1	-2	-3	-4	-5

*As defined by you in Questions 9-12.

14. These attributes are listed once more. This time please indicate how satisfied you are with these attributes as provided by the current CAPOC ECG system. (e.g., a rating of 1 means always satisfactory and a rating of 5 means never satisfactory). You can choose any number between 1 and 5 to indicate how satisfied you are. Please circle one code for each line.

	Very Satisfied				Very Unsatisfied	Not Applicable or Don't know
a. Number of hours a day STAT ECGs can be taken	60-1	-2	-3	-4	-5	-6
b. Number of hours a day routine ECGs can be taken	61-1	-2	-3	-4	-5	-6
c. Number of hours a day STAT ECG interpretations are available	62-1	-2	-3	-4	-5	-6
d. Number of hours a day routine ECG interpretations are available	63-1	-2	-3	-4	-5	-6
e. Number of diagnostic and treatment areas where ECGs can be taken	64-1	-2	-3	-4	-5	-6
f. Number of diagnostic and treatment areas where ECGs can be interpreted	65-1	-2	-3	-4	-5	-6
g. Interval between the time of a request for a STAT ECG and the time it is taken	66-1	-2	-3	-4	-5	-6
h. Interval between the time of a request for a routine ECG and the time it is taken	67-1	-2	-3	-4	-5	-6
i. Interval between the time of a request for a STAT ECG and the time the interpretation is available	68-1	-2	-3	-4	-5	-6
j. Interval between the time of a request for a routine ECG and the time the interpretation is available	69-1	-2	-3	-4	-5	-6
k. Accuracy of ECG interpretations	70-1	-2	-3	-4	-5	-6
l. Completeness (all aspects noted) of ECG interpretations	71-1	-2	-3	-4	-5	-6
m. Technical quality of ECG tracings	72-1	-2	-3	-4	-5	-6
n. Consistency of interpretations made by different readers	73-1	-2	-3	-4	-5	-6
o. Ease of reading and understanding interpretations	74-1	-2	-3	-4	-5	-6
p. Availability of prior ECG tracings for comparison purposes	75-1	-2	-3	-4	-5	-6
q. Availability of experts (cardiologists or other ECG specialists) to discuss significance of ECG interpretation in patient management	76-1	-2	-3	-4	-5	-6
r. Other (specify) _____	77-1	-2	-3	-4	-5	-6

END OF CARD 80-1

14a. If you worked at this hospital before November 1979 when CAPOC was installed, please indicate if ECG services with CAPOC have changed for the better or the worse, or if no change has taken place. If you were not here prior to CAPOC, proceed to question 14b.

	Changed for the Better	Changed for the Worse	Have Not Changed	Don't Know
a. Number of hours a day STAT ECGs can be taken	11-1	-2	-3	-4
b. Number of hours a day routine ECGs can be taken	12-1	-2	-3	-4
c. Number of hours a day STAT ECG interpretations are available	13-1	-2	-3	-4
d. Number of hours a day routine ECG interpretations are available	14-1	-2	-3	-4
e. Number of diagnostic and treatment areas where ECGs can be taken	15-1	-2	-3	-4
f. Number of diagnostic and treatment areas where ECGs can be interpreted	16-1	-2	-3	-4
g. Interval between the time of a request for STAT ECG and the time it is taken	17-1	-2	-3	-4
h. Interval between the time of a request for a routine ECG and the time it is taken	18-1	-2	-3	-4
i. Interval between the time of a request for a STAT ECG and the time the interpretation is available	19-1	-2	-3	-4
j. Interval between the time of a request for a routine ECG and the time the interpretation is available	20-1	-2	-3	-4
k. Accuracy of ECG interpretations	21-1	-2	-3	-4
l. Completeness (all aspects noted) of ECG interpretations	22-1	-2	-3	-4
m. Technical quality of ECG tracings	23-1	-2	-3	-4
n. Consistency of interpretations made by different readers	24-1	-2	-3	-4
o. Ease of reading and understanding interpretations	25-1	-2	-3	-4
p. Availability of prior ECG tracings for comparison purposes	26-1	-2	-3	-4
q. Availability of experts (cardiologists or other ECG specialists) to discuss significance of ECG interpretation in patient management	27-1	-2	-3	-4
r. Other (specify) _____	28-1	-2	-3	-4

14b. In general, how satisfied are you with the CAPOC system at this base? Would you say you are:

Extremely satisfied	29-1
Very satisfied	-2
Fairly satisfied	-3
Somewhat unsatisfied	-4
Very unsatisfied	-5
Don't know	-6

14c. Why do you say so?

_____ 30-

_____ 31-

15. Do you personally read/interpret ECGs or overread ECGs (i.e., check the interpretation made by someone else)? *(Circle as many as apply)*

	Read/interpret ECGs	32-1
	Overread ECGs	-2
Skip to Q. 20 ←	Do not do either	-3
Skip to Q. 20 ←	Don't know	-4

Answer Q. 16 - Q. 19e. only if you read/interpret or check ECGs. If you do not read ECGs proceed to question 20.

16. How many ECGs do you estimate you read in an average week? *(Write in the number of ECGs in the box at the right)*

Number of ECGs---[ ] (33 - 36)

17. How much time would you say it takes you on the average to make the following types of ECG interpretations? Please write in an answer for each line. If you don't interpret this type, circle the column on the right.

	Minutes	Seconds	Don't Interpret	
a. Interpretation of a single ECG that is within normal limits	#	#	37-1	(40 - 43)
b. Interpretation of an abnormal ECG	#	#	38-1	(44 - 47)
c. Serial comparison with a prior ECG tracing	#	#	39-1	(48 - 51)
d. Other interpretation _____ (specify)	#	#	40-1	(52 - 55)

18. How many ECG interpretations performed by others do you check in an average week? *(Write in the number of ECGs in the box at the right)*

Number of ECGs---------- [ ] (56 - 59)

19. How much time do you spend doing this in an average week? *(Write in the amount of time in the box at the right)*

Amount of Time---------- [ ] (60 - 63)

19a. With the current CAPOC system, how accurate do you feel the ECG interpretations used in the patient care are for the following diagnoses:

	Always Accurate	Usually Accurate	Often Accurate	Don't Know
a. All ECGs	64-1	-2	-3	-4
b. Normal ECGs	65-1	-2	-3	-4
c. All abnormal ECGs	66-1	-2	-3	-4
d. Rhythm abnormalities	67-1	-2	-3	-4
e. Myocardial infarctions	68-1	-2	-3	-4
f. ST-T wave abnormalities	69-1	-2	-3	-4
g. Hypertrophy	70-1	-2	-3	-4
h. Conduction abnormalities	71-1	-2	-3	-4

If you worked at Nellis prior to November 1979 and are familiar with both the current CAPOC services and previous manual ECG services, please answer question 19b. If not proceed to question 19c.

19b. When comparing computer-assisted readings with the previous manual reading, which method, in your opinion, provides better accuracy for the following types of ECGs?

	CAPOC more Accurate	Manual system more Accurate	No Difference	Don't Know
a. All ECGs	72-1	-2	-3	-4
b. Normal ECGs	73-1	-2	-3	-4
c. All abnormal ECGs	74-1	-2	-3	-4
d. Rhythm abnormalities	75-1	-2	-3	-4
e. Myocardial infarctions	76-1	-2	-3	-4
f. ST-T wave abnormalities	77-1	-2	-3	-4
g. Hypertrophy	78-1	-2	-3	-4
h. Conduction abnormalities	79-1	-2	-3	-4

END OF CARD 80-②

19c. If the computer makes errors in reading are these generally false positive or false negative errors?

False positive errors----------11-1
False negative errors---------- -2
Don't know---------- -3

19d. Since CAPOC was installed, do you think the amount of time you spend each week reading/interpreting ECGs has:

Increased----------12-1
Decreased---------- -2
Remained the same---------- -3
Other (specify) --- -4
Don't know---------- -5

19e. Why do you say so? *(write in)*

_____ 13-

_____ 14-

Finally, for background purposes only, please answer the following questions:

20. What is your professional specialty?

Staff physician (specialty) --------15-1
House staff officer (intern, resident or fellow)---------- -2
Nurse---------- -3
Corpsman or technician---------- -4
Other (specify) ------- -5

21. How long have you been working in your current job at this facility?

Less than six months----------16-1
6-12 months---------- -2
13 months or longer---------- -3
Don't know---------- -4

22. What is your military status?

Active duty military----------17-1
Civilian---------- -2
Other---------- -3
Don't know---------- -4

23. Would you like to write in any impressions or opinions you have about the ECG system at this facility?

_____

_____

_____

_____ 18-

_____ 19-

_____ 20-

21-

END OF CARD 80-③

Thank you for your time and effort. Please return this questionnaire in the attached envelope to:

Maj. T. Hablitzel/SGHP

APPENDIX B

INTERVIEW GUIDES FOR SECONDARY EVALUATION SITES

Site Visit-Interview Guide

CAPOC Sites

Facility Name:

Address:

Affiliation (? part of regional network):

Describe Area (urban, rural, remote, geography):

Usual Referral Centers? For Cardiac Problems?

CAPOC Representative:

Phone #:

Other Persons Contacted (name, position):

I. Basic Site Information (obtain from CAPOC rep.)

Type of Facility: regional hospital, local hospital, clinic

Number of Physicians _____; Cardiologists _____; IM _____

Inpatient: Number of beds _____; % occupancy _____%; admissions/year _____

Special Clinical Units: CCU, ICU, ER etc. (size of each?)

Outpatient: Outpatient visits/year _____ (by department?)

Cardiology clinic? Y/N Internal Medicine Y/N

- Describe type of clinic, frequency, patient population etc.:

Comments

*Statistical Data Available

a. Continued

Date of CAPOC implementation? _____

Has CAPOC system been working well? What problems have they had?

What is the turnaround time for different types of ECGs? STAT, pre-op, ER, routine? Probe for supporting evidence.

How satisfied have they been with the manual system?

What advantages and disadvantages do they forsee with CAPOC?

Possible advantages are: decreased turnaround time; improved tracing quality; corpsman can identify normal/abnormal interpretations; better record storage.

Possible disadvantages are: more work required; increased turnaround time for some ECGs.

c. ECG Equipment

Number of Carts _____

#3-channel transmitting _____ #1-channel _____

Location of carts by type (e.g., 3-channel-ICU):

- Mobile cart or dedicated to the location?

- Age of carts:

How/where are ECGs filed? How long kept?

List equipment acquired for CAPOC:

printer

ECG chart recorder

CRT for editing

new phone lines

What will (or has happened) to old ECG equipment?

List equipment acquired for CAPOC:

printer

ECG chart recorder

CRT for editing

new phone lines

ECG cost number _____

What will (or has happened to old ECG equipment?

II. ECG Information

a. Technician interview

Persons Contacted:

Number of Full-Time Technicians _____

Number Part Time _____ Estimate % of Time on ECGs _____%

Estimate Total Full-Time Equivalent Technicians _____
(e.g., 2 full-time plus 1 at 50% time = 2.5 FTE)

Do the technicians plan to be working at this site through 1980?

Is there a "chief technician"? Name: _____

Can we call him/her by phone for more follow-up questions later? Y/N

Phone#: _____

What days/hours do they take ECGs? (e.g., M —— F/800-1700)

How many ECG's taken 1 day? _____ Variation in daily volume?

- What happens when there is no coverage on nights and weekends (if applicable)?

How much time is spent on clerical duties e.g., typing, filing, etc.? ____ hours/per day

Is one individual responsible for these activities or do they share it?

How often are old ECG's pulled for serial comparisons?

What % of ECG's get serial comparisons?

b. Describe ECG process (example given below). Identify how process varies by type of patient or by purpose of exam (routine, STAT, pre-op, ER, annual physical, pediatrics). Are pre-ops called in or hand-delivered?

Hypothetical ECG Process

1. Order ECG
2. Forward order to Lab
3. Sort Request
4. Send technician to take ECG/patient comes to lab
5. Prepare patient
6. Record Tracing
7. Record patient information
8. Label tracing
9. Go to next patient and repeat 5-8
10. Mount ECG's for reading
11. Obtain old tracing for comparison
12. Send to reader
13. Read
14. Type interpretation
15. Copy report
16. Send ECG report to floor/bring to mail room
17. Store ECG

Estimate turnaround time for parts of process and total process where available for those reading role referred.

III. Reader Interview

Number of physicians reading_____

No. of readings per day-Inpatient Outpatient Annual Physical
(Probe for confirmation of previous tables.)

Specialty of Readers:

Cardiologist_____
Internal Medicine_____
Other (specify)

Estimate volume, or %, of ECG read by each.

Is there a usual procedure or policy for dividing up reading workload?
(E.g., does cardiologist read all the complex tracings by referral from the other readers?)

What is the reading schedule?

How much time is spent in reading?

Do they overread for other sites?

Is interpretation handwritten or typed?

When are Pre-ops and STATs read?

Serial comparison:

% of ECGs with serial comparison?_____
% where old ECG is available?_____
Under what conditions is serial comparison done?

How often are patients referred for cardiac problems?

% triggered by ECG?_____ Where referred?

Were they satisfied with manual system?

Are they satisfied with CAPOC?

What problems have they observed?

III. Reader Interview (con't)

What do they see as changes or potential changes due to CAPOC?

- Change in reading quality?
- Change in turnaround time?
- Improved tracing quality?
- Time spent reading?
- Number and type of ECGs sent out for reading?
- Are non-confirmed computer interpretations used in decisions on patient care?
- Availability of old tracings for serial comparisons due to automated storage and retrieval?

IV. Interview with MD or Nurse Users (i.e., non-readers)

Persons Contacted:

What is role with ECGs?

Are they aware of CAPOC? Describe.

What problems do they see (or have they seen) with the manual system?

Have they seen any improvements or problems due to CAPOC?

What would they like to see changed?

Do they use the non-confirmed computer interpretation in patient care?

V. Cost Information

Obtain costs on the following items:

Labor	$	/yr
Supplies		
ECG equipment maintenance		
ECG equipment repair		
Amortization of ECG carts		
Overhead		

IV. Interview with MD or Nurse Users (i.e., non-readers)

Persons Contacted:

What is role with ECGs?

Are they aware of CAPOC? Describe.

What problems do they see (or have they seen) with the manual system?

Have they seen any improvements or problems due to CAPOC?

What would they like to see changed?

Do they use the non-confirmed computer interpretation in patient care?

V. Cost Information

Obtain costs on the following items:

Labor	$	/yr
Supplies		
ECG equipment maintenance		
ECG equipment repair		
Amortization of ECG carts		
Overhead		

a. Continued

ECG Volumes for the period 10/1/78 through 9/30/79

- By location

	Central Station	Clinic	Emergency Room
October, 1978			
November			
December			
January, 1979			
February			
March			
April			
May			
June			
July			
August			
September			

a. Continued

- By patient type

	Inpatient	Routine	STAT	Pre-Op	Out-patient	ER	Annual Phys.	Other
October, 1978								
November								
December								
January, 1979								
February								
March								
April								
May								
June								
July								
August								
September								

What are the approximate percentage breakdowns of normal and abnormal ECGs for:

	abnormal	normal
inpatients		
outpatients		
annual physical		
emergency room		

CAPOC Y Period

Site Visit--Interview Guide

Date of Visit:

Facility Name:

CAPOC Representative:

Other Persons Contacted (include rank, position, etc.):

I. Basic Site Information

a. Number of Physicians by type	#	#Reading ECGs
Cardiologists		
Internists		
GP		
Flight Surgeon		
Other (or comments)		

b. Inpatient Information:

Number of beds _____; % occupancy _____

Admissions per year _____

Have there been any major changes in inpatient care during 1980 (e.g., cardiologist left staff, ER closed)?

c. Outpatient Information:

Outpatient visits per year _____

Have there been any major changes in outpatient services?

II. CAPOC Information

Date of Implementation: _____

CAPOC Cart(s): #_____ Location _____

_____ _____

Confirm Other Equipment:

DEC Writer _____ Other Printer _____ New Phone Lines _____

ECG Writer _____ CRT _____ (overread center equipment)

Major Problems with CAPOC? (e.g., carts, transmitting problems, communication lines, service, training, lost ECGs)

Probe for specific examples:

III. Equipment Information

Confirm equipment list (see attached sheets). If applicable, find out what happened to ECG machine(s) replaced by CAPOC.

IV. Benefits

For each type of ECG, find out how CAPOC has impacted turnaround time, reader, serial comparison. (Use attached table)

Confirm types of ECGs, percent of each type, mix of normal/abnormal, readers for each type.

Comments:

Turnaround Time

Did CAPOC replace mail for any part of ECG process?

How long does it take to transmit? To receive unconfirmed interpretation? Confirmed interpretation?

Do ECGs get to physicians for reading more quickly?

Do physicians read ECGs more promptly?

Is change in turnaround time sufficient to change % of ECGs meeting criteria?

	ACCEPTABLE	OPTIMAL
INPATIENT ECGs		
Routine	2 days	1 day
"STAT"	30 min.	15 min.
Pre-Operative	24 hours*	12 hours*
Emergency Room	30 min.	15 min.
OUTPATIENT ECGs		
Diagnostic (for that visit)	30 min.	30 min.
(for future visit)	3 days	30 min.
Other Screening	7 days	2 days

Reading

Are some physicians reading ECGs?

Has reading schedule changed?

Has amount of time spent on reading changed?
For normals? For abnormals?

Is unconfirmed interpretation used in patient care?

Is confirmed interpretation edited in system or handwritten on unconfirmed report?

Are pre-op or STAT/ER ECGs handled differently?

Does CAPOC help in making better interpretations?
More consistent interpretations?

Does CAPOC interpret normals correctly?

Does CAPOC interpret abnormals correctly?
Does it overcall (false-positive) or undercall (false-negative) the following:

Arrhythmia MI LVH ST-T waves

Do corpsmen or physicians' assistants confirm computer-interpreted normals?

Serial Comparison

Has % of ECGs receiving serial comparison changed?

Has file/record system changed due to CAPOC?

Do they rely on CAPOC system for all files?

Have they noticed (or do they anticipate) more old records retrieved due to CAPOC?

Other Benefits

Has quality of tracings improved?

Have referrals increased or decreased? (Can specific cases/patients be remembered?)

V. Costs

Have costs changed?

Technician Labor Costs

Do technicians spend more or less time taking ECGs? processing ECGs? filing ECGs? typing/editing ECGs?

If they save time, how do they spend it?

What percent of time is spent on ECGs? How many FTE's?

Are labor costs for ECGs recorded? Is salary information available?

Physician Labor Costs

Does reading take less time for normals? Abnormals?

How long do physicians spend reading? Per ECG? Overall?

Supplies Cost

Cost of: paper, gauze, electrodes, gel, plastic cover sheets?

Maintenance & Repair Costs

Capital Costs

Confirm equipment table

How do they amortize equipment, if applicable?

VI. General

Obtain ECG Volume by type of ECG for September 1979 through October 1980.

Indicate which ECGs are being done by CAPOC.

Describe process or confirm manual process as unchanged. Understand differences by type of ECG.

ECG Equipment | **Cost Data**

ECG Cart Number	Location	No. of Channels (1 or 3)	Transmitting (Y/N)	Manufacturer	Model	Date of Acquisition	Purchase Price	Lease	Amortization Period	Repair/ Maintenance (time/cost)