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Uses of the Electrocardiogram

Report on a WHO Study

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1. INTRODUCTION

The electrocardiogram (ECG) technique is widely used today either in the clinical evaluation of patients with cardiovascular diseases or as part of the routine examination of selected groups of patients or healthy subjects. According to a recent survey in 11 European countries the number of ECGs performed each year is estimated to range from 100 to 400 per 1000 population, and from 800 to 2500 per 1000 admissions to the general hospitals.

In addition to the conventional 12-lead ECG, other techniques are in use or being developed, like exercise ECGs, continuous monitoring of arrhythmias, and computerized ECGs. There is a wide divergency in the methodology, terminology and criteria applied in the use of the ECG. There is also a wide variation in the training and competence of physicians and technicians in the various aspects of use of the ECG.

The widespread use of the ECG has led in several countries to the development of so-called independent ECG laboratories, separate from cardiology services. This in turn has led to an increase in the number of ECGs performed – often with little justification and poor utilization. The tendency to use the ECG as an almost obligatory procedure at almost each contact of the patient with the health services has further inflated its use.

In view of this trend the Regional Office for Europe has chosen to study the uses of the ECG as one of the first research topics under its programme on appropriate technology for health. The need for an analysis of the situation and guidelines for further development in this field has been expressed by a number of ministries of health in the Region. They feel that demands are increasing, while criteria for proper use and optimal utilization are vague or non-existent.

Three consultants with ample knowledge of the subject, both from the technical and the organizational point of view, were asked to undertake the study. Professor G. Feruglio from Udine, Italy, has wide experience in ECG computerization and has organized in his city one of the few centralized, computer-assisted ECG services now available. Dr I. Gyarfas is head of the Department of Epidemiology and Health Organization of the Hungarian Institute of Cardiology which houses the ECG Coding Centre for Europe. Professor K. Pyörälä of the University of Kuopio, Finland, has been actively involved in the international standardization of computerized ECGs and has helped to develop a regional ECG service in North Karelia. In addition to profound knowledge of clinical cardiology, all three have first-hand experience in community-oriented health programmes.

Each consultant was asked first of all to review the situation in his own country. In addition, two consultants (Dr Gyarfas and Professor Feruglio) visited eight other countries in Europe. Thus the study reflects both a literature

review and information gathered on the spot in 11 countries: Austria, Finland, Federal Republic of Germany, France, German Democratic Republic, Greece, Hungary, Italy, Netherlands, Sweden, and Yugoslavia.

During the country visits, contacts were made with the relevant departments of the ministries of health and, at their advice, selected institutes were visited. Wherever possible these included a major cardiological centre, a large hospital in a city, a county hospital, and an outpatient clinic or health centre. Some general practitioners were also visited.

The main aims of the study were to (*a*) review the present uses of the ECG; (*b*) collect information on the organization of specialized services; (*c*) analyse the utilization of existing services; and (*d*) suggest guidelines for further development.

The intention was to provide public health decision makers (ministry of health officials, chief district medical officers, hospital directors) with adequate technical information on the present situation and future trends in order to assist them in making adequate policy decisions. The study was not addressed to clinical cardiologists, as this would have entailed a completely different approach. In spite of this, it might be felt that the report sometimes goes too deeply into special cardiological details. This, however, was deemed to be unavoidable, if the basic aim, i.e., helping decision makers to understand and appropriately evaluate demands, was to be attained.

It is also hoped that, although not meant for them, clinical cardiologists would read and appreciate the report, as a number of its conclusions also have direct relevance to improved organization of their work.

2. GENERAL APPLICATIONS OF THE ECG

The diagnostic information obtained from the ECG can be divided into three categories:

(1) Identification of cardiac rhythm and conduction disturbances which are primarily defined and detected by the ECG itself.

(2) Diagnosis of certain anatomical conditions and aspects of myocardial function which can be diagnosed on the basis of ECG findings with some probability of success. This category includes ECG findings of myocardial infarction, injury and ischaemia, as well as ventricular and atrial hyptertrophy or enlargement and, furthermore, ECG findings related to pulmonary disease and certain metabolic changes or drug effects.

(3) ECG abnormalities which may or may not be related to anatomical or physiological cardiac abnormalities. ECG findings of this category

include axis deviation, QRS voltage abnormalities and non-specific ST-T abnormalities. These findings may have importance in the context of other clinical information.

The ECG was originally introduced for the diagnosis of cardiovascular conditions and that is still the most important application of the technique. However, with technical progress, ECG recording has become an easy and readily available procedure, now widely used as part of the routine examination of patients who are primarily seen because of other conditions. A review of the situation showed that in the European countries almost one-half of ECGs recorded in general hospitals are taken in non-cardiac patients. Furthermore, the use of the ECG in check-ups of healthy people has been increasing.

2.1 The diagnosis and follow-up of cardiovascular conditions

2.1.1 *Cardiac arrhythmias*

The ECG has a central and established role in the diagnosis and follow-up of various types of cardiac arrhythmias. The conventional resting ECG is useful in the diagnosis of chronic forms of arrhythmias, but of limited value in the diagnosis of acute arrhythmias. The detection and diagnosis of transient or paroxysmal arrhythmias requires continuous monitoring, as carried out in coronary care units or in the ambulatory 24-hour recording by portable tape recorders (see section 3.1). The same concepts apply to the diagnosis of conduction defects. Further refinements in the diagnosis of cardiac arrhythmias or conduction disturbances can be obtained by intracardial ECG recordings in specialized cardiological centres (see section 3.3).

The introduction of ambulatory 24-hour ECG monitoring as a new and useful diagnostic method has radically changed the balance in the use of the ECG in the diagnosis of arrhythmias and conduction disturbances. Since the equipment needed is relatively expensive and requires expertise in its use, the technique has not become so widely available as it should be.

2.1.2 *Ischaemic heart disease*

The ECG makes, in addition to clinical and laboratory findings, an essential contribution to the diagnosis of acute myocardial infarction. In most instances serial ECGs taken on consecutive days after the onset of symptoms provide a correct diagnosis. Sometimes diagnostic ECG changes develop more slowly and sometimes they may be obscured by other ECG abnormalities, like intraventricular conduction disturbances. After recovery from acute myocardial infarction QRS abnormalities often diminish or disappear and therefore the diagnosis of an old myocardial infarction cannot always be made on the basis of the resting ECG. In some instances full cancellation of QRS abnormalities occurs after a new myocardial infarction.

In stable angina pectoris the resting ECG may remain normal for years. Therefore, exercise stress testing is often needed in the diagnosis of myocardial ischaemia.

In the follow-up of patients who have survived a myocardial infarction, patients with angina pectoris or patients who have been subjected to bypass surgery, a resting ECG and, if needed, ECG recordings in connexion with exercise stress testing, should be taken only as part of a complete clinical evaluation.

ECG recording is nowadays readily available for the diagnosis of acute myocardial infarction, even in small hospitals, or the patient's home. The problems in utilization of diagnostic information from the ECG, however, are usually greatest in these circumstances. Adequate training of general practitioners in the essential features of ECG diagnosis of acute myocardial infarction is very important. Furthermore, a regional ECG consultation service may be needed in cases of diagnostic difficulty.

Exercise stress testing, including an exercise ECG, requires good facilities and much expertise and should be confined to regional cardiology centres or laboratories which can provide not only exercise stress testing, but also a full clinical evaluation of the patient. The capacity for exercise stress testing is below the need in many European countries due to the quality requirements mentioned above.

2.1.3 *Hypertension*

ECG recording is part of the basic diagnostic work-up and follow-up of hypertensive patients. The frequency at which it must be done in the follow-up depends on the severity of hypertension, symptoms and the type of therapy. There may be a trend to overuse of the ECG in the follow-up of mildly hypertensive patients from the point of view of the information which can be expected from sequential ECGs. Information concerning the use of the ECG in the routine follow-up of hypertensive patients may be obtained from the WHO-coordinated programmes for community control of hypertension.

2.1.4 *Other cardiac diseases*

The ECG is used in both the diagnosis and follow-up of patients with congenital heart diseases, acquired valvular diseases, cardiomyopathies or inflammatory cardiac diseases, since in these instances ECG is always part of the overall evaluation of the patient.

2.2 Routine examination of non-cardiac patients

An ECG is nowadays taken as part of the routine examination of many groups of non-cardiac patients. In virtually all European countries, this applies

to all patients admitted to departments of internal medicine, while elsewhere the procedure is routine for virtually all adult patients admitted to general hospitals. In some countries ECG recording is routine for all patients who will undergo general anaesthesia, and in others for pregnant women. On the other hand, the practice of taking a preoperative ECG may vary between hospitals. In the Scandinavian countries the most prevalent practice is to take preoperative ECGs in all patients above a certain age (varying from 40 to 60 years) and below this limit only in patients with suspected or known cardiovascular diseases.

The practice of including an ECG in routine examinations also extends to the outpatient clinics of departments of internal medicine and to private consultation premises and community health centres where "complete" medical work-ups are done.

In widespread routine ECG recording, the prevalence of significant ECG abnormalities has been very low in younger age groups, but has shown a rapid increase with age after 40–50 years. One advantage in the practice is that base-line ECGs are available for future comparisons. Unfortunately, the base-line ECGs recorded in this way are much underutilized or not utilized at all in connexion with further contacts with the health care system, because of poor documentation of ECG findings. As a whole, ECGs taken as part of routine examinations in hospitals or outpatient departments or in primary health care probably form the most underutilized part of all ECGs recorded. Pilot programmes are in progress in some European centres to test the usefulness of computer-assisted ECG processing in improving the reporting and utilization of information from routine ECGs.

Cost-benefit analyses of various aspects of routine ECG use are unfortunately not available, but would be very important.

2.3 Health check-ups

The ECG is used in health check-ups in certain circumstances, in most of which the justification is not based on any hard medical data. Such circumstances, which vary from country to country, include:

(1) initial health examinations and regular follow-up examinations of occupational groups in mass transport, such as airline pilots;

(2) health examinations of employees in state offices, international organizations, industrial enterprises, etc.;

(3) medical examinations for life insurance;

(4) health check-up or screening examinations of middle-aged people, particularly men who are supposed to be at increased risk of ischaemic heart disease.

Exercise stress testing is often included in health check-ups and this creates additional problems because of the low predictive accuracy of exercise ECGs in a population with low prevalence of ischaemic heart disease.

3. SPECIAL APPLICATIONS OF THE ECG

3.1 Continuous electrocardiographic monitoring

This special use of the ECG allows detection of dynamic changes in the rate, rhythm, conduction and ventricular repolarization, as manifested by S-T and T wave abnormalities. The procedure can be performed in the hospital by means of a bedside recorder, telemeter (in progressive care units or rehabilitation programmes) or portable tape recorder (Holter monitoring). Portable recorders are also used for continuous monitoring of ambulatory patients outside the hospital.

3.1.1 *Inpatients*

Continuous ECG monitoring in the hospital is a standard practice in patients at high risk of developing lethal arrhythmias, such as those with acute myocardial infarction, major conduction defects or digitalis intoxication, or those who have undergone cardiac surgery or another major operation. Continuous ECG monitoring provides the basis for proper coronary care (*1*). In most of the coronary care units visited, detection, diagnosis and quantification of arrhythmias are based on human surveillance of continuous recording and on simple alarms triggered by rate changes. This approach fails to detect transient arrhythmias in a relevant percentage of cases (up to 60%) (*2*).

Some computer programmes have been developed and are in use in a minority of centres. It is felt, however, that automatic arrhythmia detection and diagnosis need further validation as to accuracy and reliability (*3*).

3.1.2 *Outpatients*

Continuous outpatient monitoring is important in assessing paroxysmal arrhythmias or conduction defects in patients with daily or frequent, rather than occasional symptoms. A careful clinical evaluation to identify non-cardiac causes of these symptoms should be carried out in all cases. Continuous monitoring may be useful to detect and control arrhythmias in patients after myocardial infarction in order to reduce the danger of sudden death. It also is important in assessing the efficacy of treatment in selected patients with symptomatic arrhythmias and in evaluating asymptomatic patients for conduction defects (a-v or bifascicular block, follow-up of pacemaker patients, etc.).

Because S-T and T changes observed during continuous ambulatory monitoring are not reliable indicators of myocardial ischaemia and can be observed in subjects with no heart disease, continuous monitoring should not be used for routine evaluation of patients with angina and is therefore not a substitute for exercise testing (*4*).

Outpatient monitoring techniques are widely accepted in Europe today. Different types of instrumentation allow reasonably reliable detection and categorization of rhythm disorders over a 12-24-30 hour period with human or computerized inspection of the recordings. Present drawbacks include the high cost of both tape recorders and scanners, and the fact that the methods for retrieval and analysis of the information are not fully reliable. Moreover, the optimal lead placement and the justification for multi-channel recorders require further evaluation.

3.2 Body surface and direct cardiac mapping

Isopotential body surface maps have been used so far mainly for research purposes. However, some practical clinical applications of the technique have been shown in the following areas: localization and sizing of myocardial infarction and areas of ischaemia; localization of the origin of anomalous sites of excitation such as those occurring in WPW syndrome, extrasystoles and ventricular tachycardias.

The technique consists of recording in over 100 ECG leads (limited to 24-32 leads in most cases) distributed over the entire chest. Data are recorded and analysed automatically by a computer.

In direct cardiac mapping, potentials recorded directly from the heart by intramural, epicardial or endocardial electrodes are spatially represented as a function of time in an integrated manner. Accepted clinical applications have been: (*a*) to localize accessory pathways in the WPW syndrome for electrophysiologic surgery; (*b*) to identify the anatomic course of the His bundle during open heart interventions in order to avoid injury; (*c*) to identify the site of origin of ectopic rhythms in patients with arrhythmias refractory to medical treatment and amenable to surgical ablation; (*d*) to delimit margins for surgical resection in the treatment of ischaemic heart disease.

The technique of surface or indirect cardiac mapping is still limited to a few specialized centres in Europe and has so far been applied only to a small number of highly selected patients.

3.3 Intracavitary electrocardiography

3.3.1 *Right heart cavities*

ECG recording in the right cavities of the heart is now being performed in many laboratories by introducing percutaneously, under local anaesthesia, one or more multipolar catheter electrodes into a peripheral vein and advancing them under fluoroscopy to various areas of the atrium, ventricle and portions of the specialized conducting system. The purpose is to determine the sequence of activation and to establish the site of the impulse formation or pathways of conduction. A simultaneous surface ECG is recorded in the three standard leads.

This technique is widely accepted today even though a careful assessment of the surface ECG and continuous ambulatory monitoring eliminate the clinical need for it in many instances. In Europe over 50% of institutions implanting pacemakers use intracardiac electrocardiography in a limited number of patients with unexplained syncope, bradyarrhythmia or chronic a-v block, to establish the presence and the site of conduction defects. Such an evaluation is based on the generally accepted observation that distal blocks (situated in the His-Purkinje system) carry the worst prognosis.

Other clinical applications of intracardiac ECG include study of the sinus node function, differentiation of aberrant supraventricular conduction from ventricular origin of QRS complex in premature beats or tachycardia, determination of the mechanism of tachycardia and evaluation of the effects of drugs.

It should be stressed that the technique has some limitations especially in the field of conduction disturbances where, apparently, it is overutilized at present. In fact, conduction defects may be labile; so a patient may show a normal H-V interval and still have trifascicular disease with intermittent distal block on different occasions. Moreover, the clinical significance of a prolonged H-V interval is still controversial.

3.3.2 *Oesophagus*

Oesophageal ECG recordings obtained with a bipolar lead provide useful information on the left atrial component of the P-wave, left atrial rhythms and myocardial infarction of the posterior wall. The technique, as well as right atrial recording, is particularly suitable for demonstrating P-waves superimposed on, or buried within, the QRS complexes. An exact characterization of the atrial rhythm assumes particular importance in ventricular tachycardia with its high incidence of retrograde conduction and in reciprocal tachycardias. Oesophageal electrocardiography should therefore be considered a necessary complement of an intracardiac ECG in selected cases.

3.4 Paediatric cardiology

In infants and children small paediatric electrodes and 50 mm paper speed recordings are generally used. In addition to the usual 12 leads, lead V_3R and V_4R are recorded.

Indications for ECG in children include clinical suspicion of heart disease, neuromuscular and metabolic disorders, electrolyte imbalance, anaemia, pulmonary disease, and possible cardiotoxic effects of antineoplastic drugs. The ECG can also be of value to assess siblings of patients with hypertrophic obstructive cardiomyopathy or with a prolonged Q-T interval or with congenital deafness.

In normal children, a baseline ECG is not considered necessary in most centres for routine preoperative studies. Variations in the normal are more diverse in children than they are in adult tracings, which makes the ECG of limited value in young subjects with atypical chest pain.

3.4.1 *Exercise testing*

Exercise testing is useful in children almost to the same extent as in adults and serves to unmask arrhythmias or conduction defects in symptomatic high-risk patients (after ventriculotomy) and to assess the progression of severity of obstruction in aortic stenosis, coarctation of the aorta and idiopathic hypertrophic subaortic stenosis.

It is probable that exercise testing is underutilized in children since its value has not yet been established in several conditions including syncope, chest pain, symptomatic arrhythmias, mitral valve prolapse, and family history of early death from coronary artery disease.

The value of exercise testing in the assessment of children for competitive sports has not been established.

3.4.2 *Continuous ambulatory monitoring*

Such monitoring in children is indicated to assess conduction defects and ventricular or supraventricular tachyarrhythmias in patients with symptoms at rest or during exercise. Specific indications include children with heart block or with an artificial pacemaker and those who are symptomatic and show bradycardia after extensive intra-atrial surgery.

4. TECHNICAL ASPECTS

4.1 Resting ECGs

4.1.1 *Instrumentation*

Recommendations issued by the American Heart Association (*2*), the US Food and Drug Administration (*3*), the International Electrotechnical Commission (*5*) and the Institute of Medical Physics (*6*) cover the currently available performance requirements of single- and multi-channel ECG recorders for conventional ECG recording.

Direct writing ECG instruments are used throughout Europe. Single-channel recorders are still widely used, not only as portable or emergency instruments, but also for routine work. The use of multi-channel recorders

which have the advantage of more efficient recording and easier, more reliable interpretation is increasing, but has so far not become as common as it ought to be in laboratories recording large numbers of ECGs. More sophisticated automatic multi-channel recorders are being introduced, mostly in connexion with computer-aided systems.

The performance characteristics of the various types of recorder vary widely and do not always meet the technical requirements defined by the above-mentioned bodies. Moreover, periodic checking of the performance of ECG equipment is often neglected.

4.1.2 *Recording technique*

The conventional 12 leads are used throughout Europe, although additional leads are still used in some countries. In the majority of countries 25 mm paper speed is used in the recording, although in the Scandinavian and the German-speaking countries 50 mm paper speed is in use. The technical skill of the personnel recording ECGs seems to leave much to be desired. Useful recommendations concerning the requirements and form of training for ECG technicians have been given (*7*).

Continuous quality control requires that the performance of the recording instruments is continuously checked, as mentioned above. At the same time the performance of ECG technicians must be continuously checked by the physician or cardiologist responsible for ECG interpretation. For effective feedback, the identification of the technician should be given on each ECG tracing.

4.1.3 *Interpretation and reporting*

Throughout and within the European countries a great variation has been observed in the ways of analysing and reporting ECGs. Some hospitals or laboratories give a full description of the ECG record, measuring all parameters and making a synthetic report, while others give only summary statements and some include only brief comments on the ECG in the consultation report or in the patient's medical record. It appears to be not uncommon, even in hospitals, for formal reporting on ECG findings to be completely omitted.

The overall impression of the situation in the countries is that the thoroughness of ECG interpretation and reporting has been degrading with increasing numbers of ECGs being recorded. Efforts should be made to improve the practice in this respect. A complete ECG report should include:

- patient identification and information data (name; patient identification number, if available; age; sex; clinical diagnosis; medication; etc.)
- basic electrocardiographic measurements

– description of ECG morphology
– interpretation (rhythm, diagnostic statements, comparison with earlier ECGs, clinical conclusion).

The main purpose of the ECG interpretation and reporting is to help the clinician in the management of the patient or in the evaluation of the cardiovascular status of an apparently healthy subject. In those instances where clinicians interpret ECGs of their own patients, the form of ECG reporting may be modified and simplified, but it is important that the essential ECG findings are documented in the patient's medical record.

Better standardization of the terminology used in ECG reporting is highly desirable. Recommendations with respect to terminology and interpretation have recently been issued (*8*).

4.2 Exercise ECGs

4.2.1 *Instrumentation*

Direct writing multi-channel ECG instruments are used throughout Europe in exercise ECG recording. More sophisticated, automatic instruments are used for data acquisition in some cardiological centres with computerized ECG processing systems.

Exercise stress testing in routine clinical work is carried out in most European countries using a bicycle ergometer with either a mechanical or an electrical braking system. It is more difficult to check the calibration of electrically braked ergometers than mechanically braked apparatus. This and the "belief" in the superiority of electrically braked ergometers leads often to a neglect of regular calibration of their ergometers. It should be noted that while with mechanical ergometers a simple correction factor can be used in case of incorrect calibration, there is no linearity in the case of electrically braked ergometers, hence correction by calculation is not possible.

4.2.2 *Technique of exercise ECG recording and stress testing*

The quality of ECG recording in connexion with exercise stress testing is improving due to the use of better electrodes and electrode cables and more attention to careful skin preparation, leading to an improved signal-to-noise ratio. Good training of the personnel doing exercise ECG recordings and continuous quality control are essential and seem to be carried out more carefully in this context than in the routine recording of resting ECGs.

The lead systems used in the ECG recordings before, during and after exercise stress vary widely. Most laboratories, however, record a 12-lead ECG before and after exercise and an ECG of at least 3 chest leads, unipolar or bipolar, during exercise. Also the positioning of the patient during

the recovery period varies. In some laboratories post-exercise recordings are made with the patient in the seated position, whereas in others post-exercise recordings are made with the patient in the recumbent position.

There is a wide variety in the protocols of exercise stress testing. In bicycle ergometer stress testing with the patient in the upright position the most common test protocol is that of continuous, step-wise load increment, starting from 25 W with 25 W increments at intervals of 5-6 minutes (*4, 9, 10*). Target heart rates of 75%, 85% or 90% of the age-predicted maximum heart rate are used as criteria for stopping the test in subjects who do not develop symptoms, clinical signs or ECG signs which would indicate stopping earlier. Maximum exercise stress tests are carried out for special purposes in the assessment of asymptomatic and healthy subjects.

In exercise stress testing with treadmill the Bruce-type protocol, widely applied in the USA, with continuous, step-wise load increments at 3-minute intervals is mostly used. Simple step or ladder exercise stress tests are used to some extent, particularly in connexion with rehabilitation programmes.

ECG monitoring and recording during exercise and frequent recording of non-ECG parameters, such as blood pressure, heart and respiratory rates, are essential for patient safety, and also for maximum diagnostic yield. A physician well trained in exercise stress testing should supervise the procedure, and emergency equipment for cardiopulmonary resuscitation should be available and ready for use. In some European countries regulations have been issued on patient safety aspects of exercise stress testing, but apparently this point requires more attention. Contraindications to exercise stress testing are described in publications of WHO (*4*) and the International Society of Cardiology (*11*).

4.2.3 *Interpretation and reporting*

Although the criteria for interpretation of exercise ECG and exercise stress testing as a whole have continued to improve, there still is a lot of controversy. Despite this, the general impression is that in the European countries more careful attention is paid to the interpretation and reporting of exercise ECGs than to the interpretation and reporting of resting ECGs. Better standardization could, however, be achieved at the European level.

4.3 Computer-assisted ECG processing

The use of computer-assisted ECG processing is increasing in Europe, following a similar trend in the USA and Canada. The situation has recently been reviewed in the member states of the European Community (*12*). The situation in Europe was also summarized in the report of an international workshop on trends in computer-processed electrocardiograms, Amsterdam,

3-5 November 1976 (*13*). To develop common standards for computer-assisted ECG analysis, a four-year collaborative project has been started within the European Community (*14*).

In the various sytems in use, the data collecting unit consists of a 3-channel automatic electrocardiograph. Analog to digital conversion occurs at a rate of 250-500 samples per second. Remote transmission of data, in analog or digital form, is done through regular telephone lines. Some programmes utilize the conventional 12-lead ECG, but some others use additional leads such as Frank orthogonal leads, or use both lead systems. Different approaches to interpretation, viz. heuristical versus statistical, are also used. Some outstanding problems to be overcome are the lack of uniform diagnostic criteria, unsatisfactory methods for programme accuracy evaluation, and the high initial costs of the equipment. These limitations are counterbalanced by the provision of a high quality ECG analysis; the availability of a quick record and interpretation, also for remote users, within a few minutes; the improved possibilities for comparing the present analysis with previous results; and the availability of better facilities for maintaining a certain standard of electrocardiology within the area.

5. ORGANIZATIONAL PROBLEMS

The organization of ECG services in individual countries depends on the organization and development of health services, on geographical factors, and on population density. A review of the situation in several European countries indicated, as expected, a wide variety in the organization of ECG services between countries and often also within them.

5.1 ECG services in different health systems and at different levels of care

5.1.1 *ECG services at primary care level*

In some countries general practitioners, or district physicians, are equipped with single-channel direct writing electrocardiographs, and perform ECG recordings and interpretations themselves, whereas in others the physicians have access to special ECG services organized in two ways: (1) independent ECG services organized only for ECG recording and interpreting, and (2) cardiological services performing ECG recording and interpretation as part of cardiological consultation. In specially organized health services, and in group practice where 4 or 5 district physicians work together, multi-channel electrocardiographs are often used, and ECG recordings are usually taken by nurses and interpreted by general practitioners themselves. Studies carried out in

some countries (e.g., Greece, the Netherlands) have shown a misinterpretation of ECGs by primary care physicians in 10–40% of cases. In the Netherlands there are several pilot projects designed to improve ECG services at the primary health care level. In Leiden 18 general practitioners are served by an ECG laboratory connected with the Leiden University ECG computer centre, and giving the tracing and computer interpretation as well as an ECG diagnosis and recommendations for further cardiological examination, if necessary. In another study (cardiophony) a telephone transmission link with the Utrecht University computer centre has been established in general practitioners' offices. In Rotterdam, based on the experience gained in the imminent myocardial information research study, special services have been organized to help general practitioners in their cardiological diagnosis, especially for myocardial infarction.

In Skövde (Sweden) the clinical physiology laboratory of the county hospital has taken over responsibility for improving the performance of primary health care ECG services both in the technical aspects and in the interpretation. These pilot projects are promising with respect to the future organization of ECG services at the primary care level, but at present most of the services at this level are unorganized.

5.1.2 *ECG services in hospitals*

ECG services for inpatients are centralized in many of the large hospitals and university clinics, i.e., almost all the ECG tracings and reports are provided by these centres, while in other hospitals all departments have their own ECG services and there is no element of centralization. Between these two extremes, partly centralized ECG services have been arranged in some hospitals, whereby the cardiological department or one of the medical departments gives ECG services to the other departments of the hospital. Often a surprising lack of coordination in ECG services within hospitals was found, e.g., in one of the university hospitals having a cardiological department with computer-assisted ECG processing of high reliability the other departments did not use this facility for their ECG work although even telephone transmission was available.

Most hospitals in the different countries provide services to patients with cardiovascular diseases within their outpatient clinics. However, both the practice with respect to ECG services and the organization of outpatient services vary greatly within and between countries. Some hospitals base their cardiology outpatient clinics in one medical department, whereas in others the different medical departments give separate outpatient consultations in cardiology. Most outpatient clinics use ECGs only as part of a full cardiological or medical consultation, whereas others also offer ECG interpretation as a separate item.

5.1.3 *ECG services in outpatient clinics outside hospitals*

Independent outpatient clinics are organized in some countries. Their work is similar to that of outpatient clinics in hospitals, and consists mainly of providing consultation in cardiology but in some countries they also function as ECG laboratories. Depending on the health care system, patients can contact outpatient clinics or hospitals through their general practitioner or district physician, or on their own initiative. The differences in organization are difficult to evaluate without due consideration to the basic characteristics of the particular health care delivery system. It is beyond doubt, however, that in theory independent ECG laboratories are most likely to succumb to misuse (e.g., over- and underutilization of information).

5.2 Exercise ECG examinations

Exercise ECG examinations are carried out mainly by hospital inpatient and outpatient clinics. In this instance exercise tests are always supervised by a specialist, who is either a cardiologist, an internist or a clinical physiologist. The exercise tests are done mainly using an electrically braked bicycle ergometer and, in a smaller proportion of cases, a treadmill; step tests are not much used at these levels.

In some countries general practitioners also perform exercise tests, using step tests or a bicycle ergometer. In the general practitioners' offices where exercise tests are carried out, defibrillator and other equipment for cardiopulmonary resuscitation is usually lacking. The explanation given for performing exercise tests without this safety equipment is that the general practitioners use the exercise tests mainly for rough diagnostic purposes and for the reassurance of patients, the basic assumption being usually that the patient is unlikely to have ischaemic heart disease. The proportion of exercise tests among all ECGs taken by different ECG services varies within a range of 1-10%.

5.3 Special applications

5.3.1 *Continuous ambulatory monitoring*

Continuous ambulatory monitoring is already carried out in large cardiological centres, but in many European countries the introduction of this technique in practice is still under way. The proportion of continuous ambulatory ECG recordings among all ECGs taken by centres using this technique varies within a range of 0.1-2%. Computer-assisted arrhythmia detection and diagnosis will obviously result in increased utilization of ambulatory continuous ECG recording. There may be a need in the future to develop regional service systems for the analysis and reporting of continuous ambulatory ECG recordings; a regional cardiological centre could thus provide a service to other hospitals and outpatient clinics within the region.

5.3.2 *Other*

Vectorcardiography is done only in a small minority of larger cardiological centres. Body surface mapping is also very rarely performed and mostly for research purposes. Intracavitary ECG recording is included in the diagnostic array in the majority of large cardiological centres or departments with clinical physiology or haemodynamic laboratories.

5.4 Quality control

Organized quality control of the performance of ECG services has so far been an almost entirely neglected area throughout Europe. Optimal arrangements for organizing quality control will vary according to the system of health services in each country. In those countries where health services are provided by the community, regional cardiology departments should be responsible for quality control of ECG recording and reporting. In countries with different systems, other arrangements will be necessary.

Training programmes for primary care physicians, hospital internists, paediatricians and other physicians using the ECG technique in their routine work should be organized by regional cardiological centres, medical faculties or professional cardiological societies. Postgraduate courses and practical training courses should be arranged. Periodic continuing education courses should be organized to enable physicians to update their knowledge.

To maintain high quality ECG recording, standards on equipment should be accepted by all services. One of the main requirements in good electrocardiography is the use of proper recording techniques by the ECG technicians.

Periodic checking of the performance of equipment is of great importance. It can be organized by cardiological centres using their own engineer for the purpose, as has been done in a pilot project in Sweden or using special services, as in the case of X-ray equipment.

5.5 Cost containment

The cost of an ECG, from its recording to its interpretation and reporting to the consumer, comprise:

- the costs of the ECG equipment (purchase and maintenance) and material needed (ECG paper, etc.);
- the costs of salaries of personnel (technicians recording ECGs, physicians interpreting and reporting findings, clerical personnel, etc.);
- the basic costs of maintenance of ECG services within the hospital, outpatient clinic, community health centre or private practice.

The costs of salaries of personnel form the largest proportion of the overall costs of an ECG service and the size of this component depends on several factors, such as the volume of ECG recordings, the type of equipment, the form of organization of the ECG service as part of the work of the department or a health care unit, the proportion of abnormal tracings, etc.

The use of a proper type of ECG recorder in relation to the volume of ECG recordings is relevant with respect to the technician's time needed in ECG recording. While an ECG service for solo general practice needing a small number of ECG recordings, e.g., 10 per day, can be efficiently operated with a single-channel recorder, the use of a multi-channel recorder saves much of the technician's time in hospitals, outpatient clinics and practices needing larger volumes of ECG recordings. In addition, ECG recordings made by a multi-channel recorder are superior with respect to interval measurements and some other aspects of ECG interpretation. Single-channel recorders are still used in many European countries in circumstances in which the use of multi-channel units would be more appropriate.

The physician's time spent in the interpretation and reporting of ECG findings is apparently the cost component showing the greatest variation according to the setting in which ECGs are taken and used. As pointed out in section 4.1.3, the thoroughness of ECG interpretation and reporting seems to leave much to be desired in many European countries. It would be of great importance to pay more attention to the physician's part in ECG services and to analyse how much of his time is needed in ECG interpretation and reporting in different circumstances.

Information concerning total cost containment in ECG services was found to be very scanty. In one study in Sweden the cost per ECG in a large hospital was about 10 US dollars (*15*). Another study on ECG services at primary health care level in two Finnish community health centres showed a cost per ECG of about 8 US dollars, not including the cost of the physician's time (*16*). Cost containment analyses of ECG services should be an essential part of attempts to rationalize and develop the services.

Computer-assisted ECG processing saves much of the physician's time in interpretation and reporting, since in most computer-assisted systems only the ECGs reported to be abnormal by the computer need to be checked by the "overreading" physician. In a computerized system, however, there are additional costs, such as basic costs of the computer and the costs due to transfer of ECG signals by telephone when giving ECG services to distant hospitals or health centres. In a computer-assisted system the cost containment is greatly dependent on the number of ECGs processed. Thus, it is estimated that the cost of an ECG will fall by almost two thirds if a computer deals with 3000 ECGs in a month instead of 1000. There are studies showing that the cost per ECG would be less using a computer-assisted ECG service rather than a conventional service, but there is still a need for further studies concerning the benefits of computerized ECG systems.

6. NEEDS AND UTILIZATION

6.1 Primary care level

To a certain extent, needs for the ECG are defined by the general applications (section 2) of the technique. In addition to purely cardiological considerations, needs are also influenced by the attitude of the medical profession and of the public, by the prevalence and incidence of cardiovascular diseases, by established norms of medical conduct, by existing legislation and a number of other factors. This chapter should therefore be interpreted in conjunction with section 2.

Attitudes towards the ECG show a wide variation between – and even within – countries in Europe. There are still places where the procedure is regarded as a sub-discipline or service *per se*, although the tendency is towards viewing it as one, albeit important, part of overall cardiological work-up. This is, of course, reflected in perceived needs; more ECGs are requested (hence more facilities are made available) in the former case than in the latter. Interestingly, but not surprisingly, proper utilization of the information furnished by the ECG is in general inversely related to the existence of specialized and independent ECG services. Where ECG has become a routine, performed without asking a specific question, its utilization also becomes a routine, i.e., poor. Apart from the excessive use and underutilization of the received information, mostly due to lack of adequate knowledge of ECG interpretation, there is a distinct secondary danger bound to this approach. Simple and often more relevant clinical investigations are neglected and omitted, on the ground that "the ECG will show it anyhow". Such attitudes in the medical profession have spread with relative ease to the population as well. The expectations – sometimes direct requests – of patients (or would-be patients) are increasingly including ECG as an obligatory service, part of any "proper" clinic attendance. Brief mention should also be made of ECG iatrogeny ("I feel well, but my ECG is bad", etc.).

Unfortunately there are no reliable studies on why, when and how frequently an ECG should be made in general medical practice, in routine health check-ups or in occupational medicine. The healthy trend in cardiological practice to regard and use ECG as but one part of the whole work-up is only poorly reflected in the above fields. However, they account for the bulk of ECGs in any given country. Should use in fact reflect real needs, one would expect a similar north-west to south-east declining trend between countries in Europe as it is seen in the prevalence and incidence of coronary heart disease. Although there are no good data on this issue, the country visits in connexion with the study did not confirm this expectation.

The potential of the ECG to detect otherwise hidden functional disturbances (e.g., conduction defects), and the defensive attitude of the medical

profession towards official, professional or individual malpractice claims, tend also to inflate demand. This approach may even become codified, e.g., making ECG obligatory at each pre-employment or reassignment check-up.

There is even less general agreement on how often an ECG should be repeated in different age groups, professions, diagnostic categories, etc.

Turning attention from needs to utilization, the picture is not much brighter. The two basic prerequisites for proper utilization, i.e., acceptable technical performance and basic skills in interpretation, have been dealt with already under different headings. The latter requirement still poses major problems at the primary health care level. The main reasons for this are differences in basic education (e.g., between young and old physicians), lack of adequate *problem-oriented* postgraduate training, inadequacies of referral systems and criteria for ECG utilization, etc.

Utilization is often inefficient because of poor reporting (even for the physician's own file) of the tracings, deficient filing and the ensuing difficulties of data retrieval. An ECG is often repeated simply because the earlier one is missing, its description is poor or there is lack of confidence in other people's performance. Several encouraging attempts are now being made throughout Europe to remedy these defects. Telephone referral centres, computers, etc., are potential fields for improvement, but no modern system will probably be able to forgo the need for imparting and maintaining basic interpretation skills at the primary care level.

6.2 Secondary care level

6.2.1 *Outpatient clinics*

Needs are usually well defined when the ECG service is part of an existing cardiological clinic. Both so-called routine and special recordings are in this case decided upon, executed and evaluated by the cardiologist. Although perceived needs may vary from individual to individual, this variation has its developmental advantages and is contributing little to the inflation in demand.

The problem is more difficult in outpatient clinics with no cardiologist on the staff. In some countries and in some smaller outpatient clinics this situation tends to contribute to the creation of "independent" ECG units, freely accessible to any physician on the staff or having access to the service, without indicating the need or specifying the diagnostic problem. This is usually coupled with inadequate evaluation, and poor filing and retrieval.

6.2.2 *Hospitals*

The main needs of the physicians are to be able to read ECGs of their own patients and to have access to cardiological opinion in problem cases. In

smaller hospitals, physicians with an interest in cardiology are usually responsible for much of the routine reporting of ECGs and in many cases assume a training role in this field. Consultations given by these physicians should not be confined to interpreting ECGs but should consist of an overall cardiological assessment of which the ECG is a part.

A preoperative ECG with expert interpretation is necessary in patients with a history of myocardial infarction or other cardiovascular diseases. These patients are more likely to suffer further incident after operation. In some situations an intraoperative ECG gives an immediate indication of cardiac function, with interest focused on rate, rhythm, and ischaemic changes due to anaesthetic drugs and surgical procedures. In most routine cases a preoperative ECG is not obligatory, but it becomes more valuable in debilitated and at-risk patients. In several places routine preoperative ECGs are taken on all adult patients to provide a recent baseline record to help to manage surgical complications (cardiac or pulmonary complications, electrolyte imbalance, etc.). There is insufficient evidence to support any of these practices, meaning that real needs are poorly – if at all – established.

In general, due to the higher organizational level and skills available, misutilization is less likely to occur at the hospital level, especially if the so-called routine procedures (e.g., an obligatory preoperative ECG) are re-evaluated from time to time.

One important aspect, however, is often neglected, i.e., the standardization of ECG equipment. In many hospitals different types of equipment are installed in different or even in the same department. These differences are usually not related to performance, only to producers. These variations tend to inflate costs of purchase and maintenance (servicing possibilities are often neglected). Uniform mounting and filing also become more difficult.

7. EDUCATION AND TRAINING

The quality of electrocardiographic recordings and their interpretation depends upon the education and training of physicians and other health personnel connected with the ECG services. Electrocardiographic quality begins with the skill of the recording technician and culminates in the clinical interpretation of the tracing.

7.1 Technicians

Proper ECG recording technique is of utmost importance in good electrocardiography. There are different levels of requirement, from minimum skill for technicians in the conventional recording of resting ECGs to advanced

skill for experienced technicians in cardiac laboratories who, besides recording ECGs at rest and during exercise with standard equipment and computer terminals, interpret continuous ECG monitoring data and record other non-invasive and invasive cardiac performance tests. In many countries, however, technician training is neglected in the most widely used services, i.e., at the primary and lower secondary care levels.

7.1.1 *Training requirements*

The training must enable the technician:

- to recognize artifacts due to improper electrode application, power-line interference, muscle tremor, coughing, respiratory variation, etc.;
- to recognize patterns that require additional electrocardiographic recordings;
- to ensure the proper format of recording;
- to ensure proper electrode application (correct position, proper skin preparation, proper position and relaxation of the patient);
- to use booklets giving instructions for use and maintenance of equipment;
- to have a general understanding of ECG theory and to recognize arrhythmias;
- to recognize signals indicating that the manufacturer's maintenance checks need to be carried out.

The following means of training are useful:

- training manual;
- apprentice-like approach;
- before starting to practise, submission of tracings recorded by the trainee to an experienced electrocardiographer;
- continuing quality control, with immediate feedback from the electrocardiographer who interprets the tracings.

A periodic summary showing the proportion of poor quality tracings can be used to determine the need for retraining.

Special professional schools might be established for training of high-level technicians, as was done in Italy.

7.2 Physicians

The education of physicians involved in ECG interpretation should be organized by cardiological departments or sections, or cardiological societies,

where cardiologists are available to give courses of instruction. Electrocardiography is a laboratory procedure that must be applied and intepreted in the context of the clinical problem. An ECG interpretation provided with knowledge of the clinical problem is more likely to be correct than one provided on the basis of the tracing alone. ECG training should include experience with a wide variety of ECG recordings including tracings from acute cardiac disorders, such as myocardial infarction and arrhythmias. Education programmes for all physicians (district physicians; general practitioners; hospital physicians working in the field of internal medicine, paediatrics, emergency medicine, etc.) should ideally include a formal rotation through ECG units that provide trainees with the learning experience of supervised interpretation of several hundred tracings. Periodic continuing education courses aimed at updating ECG knowledge should be made available.

8. CONCLUSIONS AND RECOMMENDATIONS

1. The application of the ECG as part of the evaluation of patients with cardiovascular diseases has long had an established place in hospitals and outpatient clinics, but nowadays the technique is also used increasingly at primary health care level. Thus, improvement of the quality of ECG services at the primary care level has become a problem of central importance.

2. The ECG is widely applied as part of the routine examination of non-cardiac patients in hospitals and outpatient clinics. The large volume of ECGs thus produced is apparently much underutilized due to poor documentation, problems in filing, etc. The practice of including an ECG in preoperative examinations varies widely between and within the European countries; in some countries an ECG is taken in all patients before general anaesthesia, whereas in others the prevalent practice is to take an ECG in all surgical patients above a certain age (which varies from 40 to 60 years in different centres) and below that age only in patients with suspected or known cardiovascular diseases. Further research is needed to define the proper use of ECGs as part of preoperative examinations.

3. There appears to be a trend to increasing use of ECGs as part of various kinds of health check-up or screening examinations, although the medical justification for this application is weak or lacking except in the case of life insurance examinations and health examinations of occupational groups in mass transport, such as airline pilots.

4. Exercise stress testing in the diagnosis and follow-up of patients with cardiovascular diseases or in the evaluation of their functional capacity should

be confined to regional cardiological centres or to other large laboratories with good facilities and expertise, not only in exercise testing, but also in the clinical evaluation of patients with cardiovascular diseases.

5. Among the special applications of the ECG, body surface and direct ECG mapping and intracavitary electrocardiography are confined to highly specialized cardiological centres and to a large extent this also applies to ECG applications in paediatric cardiology. On the other hand, continuous ECG monitoring for the detection of arrhythmias has become a routine part of the acute-phase surveillance of patients with myocardial infarction in hospitals throughout Europe. Continuous ambulatory ECG monitoring by means of portable tape recorders is increasingly used in the diagnosis of arrhythmias and conduction disturbances. Since the equipment needed in the analysis of such ECG recordings is relatively expensive and requires good expertise in its use, the technique is best applied in large regional cardiological centres. There may, however, be a need to develop regional services for the analysis and reporting of continuous ambulatory ECG recordings taken by other hospitals and outpatient clinics within each region.

6. Direct writing multi-channel ECG recorders are the most suitable instruments for hospitals and laboratories recording large numbers of ECGs, because they allow more efficient recording and easier, more reliable interpretation than single-channel instruments. Single-channel ECG recorders, however, continue to be acceptable in some applications at the primary health care level.

7. National arrangements are necessary to ensure checking of the technical characteristics of new ECG equipment and for including ECG equipment among the medical intruments needing periodic checking.

8. With increasing numbers of ECGs being recorded, the thoroughness of ECG interpretation and documentation appears to be degrading. Efforts should be made to improve the practice in this respect. Better standardization of the terminology used in ECG reporting would be highly desirable.

9. There is much diversity in exercise ECG recording and interpretation, as well as in the methodology of exercise stress testing. A review of the situation and the development of recommendations aimed at better standardization could be undertaken by a European expert group.

10. Work is in progress in Europe aimed at improved standardization for computer-assisted ECG analysis. A similar approach may become necessary with respect to other special applications of the ECG.

11. Since the use of the ECG at the primary health care level is of increasing importance, there is a definite need to strengthen the performance of ECG

services at this level. Special and refresher courses for primary health care physicians are needed to improve and maintain their skill in ECG interpretation. In addition, such physicians need easy access to specialist consultation in ECG interpretation. Whenever possible, cardiologists or physicians at regional hospitals should provide help for primary health care physicians both in their training and in giving help in the interpretation of difficult ECGs. The training of ECG technicians and checking of the technical performance of ECG equipment are other areas in which regional hospitals could give help to physicians working at the primary health care level.

12. ECG services in large hospital departments and outpatient clinics are, in both a qualitative and a quantitative sense, best organized as a centralized, dedicated ECG facility, whereby a department of cardiology, medicine or clinical physiology takes the responsibility for organizing the recording of ECGs for the whole hospital. This service can include ECG interpretation and reporting for departments and specialties less familiar with electrocardiology. Despite the definite advantages of a centralized ECG service within hospitals this organizational model has so far not been widely applied in some European countries.

13. Further research is needed to study cost containment for different organizational models of ECG services at the primary health care level and in hospitals. Further studies are also needed to compare the costs and benefits of computer-assisted ECG services with those of conventional ECG services.

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