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CLINICAL CHEMISTRY DIVISION

COMMISSION ON TEACHING OF CLINICAL CHEMISTRY*

in conjunction with

INTERNATIONAL FEDERATION OF CLINICAL CHEMISTRY†

COMMITTEE ON EDUCATION*

A SCHEME FOR A TWO YEAR POSTGRADUATE COURSE IN CLINICAL CHEMISTRY

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CONTENTS

1. PREFACE

The clinical chemist

That the Clinical Chemist plays an essential role in the diagnosis and management of patients is now widely accepted. The IFCC Committee on Education and the IUPAC Commission on Teaching of Clinical Chemistry considered that it would be helpful to prepare a syllabus for a training program, suitable for those who supervise service laboratories. The course outline is for graduates in an appropriate science subject.

The Clinical Chemist fulfills many roles. Perhaps first and foremost he must be a reliable and respected analyst providing his results with the speed demanded by the condition of the patient and the suspected diagnosis. With this role in mind much of the suggested course is concerned with analytical techniques. The Clinical Chemist is, however, in the vanguard of the scientists who play an increasingly important role in the multidisciplinary team which is involved in diagnosis and management in modern medicine. It would, therefore, be more than a pity if the Clinical Chemist holding a responsible position in the service laboratory were merely to be considered by his medical colleagues as a reliable analyst. Equally important is an understanding of the implications of his analytical findings and an ability to convey to his medical colleagues an integrated interpretation of clinical and analytical aspects.

The role of the Clinical Chemist will vary considerably according to the circumstances in which he finds himself. He may be employed in a large modern laboratory in an industrial country or is perhaps stationed in a small community hospital in a developing country. In any event he should be regarded by his medical colleagues as a person with a lively mind who is ready to give his opinion concerning the validity and interpretation of laboratory results for which he is responsible. He should remember that he will probably have a much better concept of the quantitative significance of his results than will his clinical colleagues and for this reason, he must realize that he should be his own severest critic.

For the Clinical Chemist to be prepared to offer suggestions concerning the interpretation of his results, he must have a sound background of medical biochemistry. The training program should provide an opportunity to remedy any shortcomings in this respect; e.g., selected reading and attendance at ward rounds, case discussions, clinico-pathology conferences and special meetings.

Since Clinical Chemistry is a rapidly growing subject, no course can be an end in itself - rather it should be regarded as a beginning which lays the background and encourages the student to develop the habit of self-instruction. We would like to suggest, therefore, that the student devise a reading program of the journals appropriate to his continuing education. To keep abreast of current literature, fertilizing the mind with new ideas, is essential if the Clinical Chemist is to gain and maintain the respect of his clinical colleagues.

2. COURSE OUTLINE

A two year program leading to an M.Sc. or Diploma in Clinical Chemistry is proposed as part of the training of clinical chemistry specialists capable of undertaking supervisory roles in clinical chemistry service laboratories. The course places primary emphasis on the development of technical-analytical and managerial skills, with adequate but relatively less emphasis on the clinical-interpretative aspects of clinical biochemistry. Graduates of such a program would be expected to have advanced capabilities in such areas as method development and evaluation, quality control, trouble-shooting and minor repair of general laboratory equipment and general organization of workloads and technical staff. These duties would be carried out under the immediate direction of the laboratory director or qualified alternate.

It is recommended that the primary faculty and facilities be located centrally in a university department which for preference has service responsibilities, such as a department of Clinical Biochemistry in a teaching hospital. However, other settings which may be suitable include departments of Chemistry, Biochemistry, or Pharmacy provided that there are close links with a general hospital. Lectures and tutorials would be organized and presented by the university department with definitive interaction with the facilities of university departments of Chemistry, Biochemistry, Biology, Medicine and the clinical chemistry laboratories in affiliated hospitals. An advisory council composed of university faculty and hospital staff should be established to take responsibility for the development, coordination and conduct of the program. Additionally, it is expected that the IFCC through its Committee on Education in Clinical Chemistry, if requested, might assist in the development and evaluation of the program and in arranging for lectures and seminars by outstanding visiting lecturers.

It should be emphasized that the course to be described will require a full-time, two year registration and follow a structured curriculum, as distinct from the more general program of training for the Clinical Chemist which must last longer than two years and encompass additional aspects, e.g., hospital organization and administration, functional interrelationships of the medical and laboratory disciplines, etc.

Course objectives

1. To teach the fundamental principles of clinical chemistry through a systematic course of lectures and tutorials.
2. To ensure that candidates achieve a high degree of practical competence in routine analyses and techniques through a program of supervised training in a hospital clinical chemistry laboratory.
3. To develop special skills in the use, maintenance, trouble-shooting, and minor repair of analytical instrumentation and general laboratory equipment.
4. To train students in the techniques of method development, method evaluation, quality analysis and control, laboratory management and assessment of medical usefulness of tests.
5. To provide a fundamental understanding of the clinical aspects of work performed in the clinical chemistry laboratory, through lectures, selected reading and attendance at appropriate ward rounds.
6. To stimulate the student to explore, by means of basic, applied or clinical research, certain aspects of the biochemical changes that accompany disease processes.

Prerequisites

Candidates must have a university degree or equivalent qualification in chemistry, biochemistry, medicine, pharmacy, or medical technology. Undergraduate work will usually have included courses in mathematics (including basic statistics), physics, biology, general, organic, analytical and physical chemistry, biochemistry and physiology.

Structure of course

Student(s) would be assigned to a hospital clinical chemistry laboratory where the director of the laboratory would act as supervisor of the student(s) working in his laboratory. A structured course of lectures and demonstrations should run through the whole period. If the services of foreign teachers are called upon, it would be more practical to present the course in blocks of one or two weeks. In any case, the courses should be integrated as much as possible with the in-service training program.

Lecture course

An outline of the program is provided in the Syllabus (below). Much of this material can be covered informally during the in-service part of the program in the form of seminars and discussion periods with the director of the program and/or senior clinical chemists. A formal lecture program, however, should be developed and presented centrally to all students in the program. A lecture course which integrates analytical chemistry and biochemistry with physiology and "pathological chemistry" should be based on the topics outlined in Section 3.6 of the Syllabus. This course should provide an appreciation of the biochemical and physiological factors involved in the maintenance and alteration of organ and tissue function. Equally important, the student should gain an understanding of the significance and limitations of the laboratory determinations involved. Supplementary lectures or seminars by outstanding visitors should be encouraged.

It is recognized that the particular needs for clinical chemistry services and the resources available differ from country to country. For these reasons the proposed course outline (Syllabus) should be regarded as a guide for the development of a program appropriate to a particular country's needs and resources.

In-service training

Students would systematically rotate through each section of the routine service laboratory to gain experience in the practical aspects of clinical chemistry. The student's progress should be evaluated weekly through informal discussion with the laboratory director and other members of the professional staff as available. A formal evaluation of the student's progress should be conducted at six monthly intervals. When the student has demonstrated that he has acquired the required level of practical competence and knowledge, he should be given short term supervisory responsibility for the work of that area or section before moving on to his next assignment. It would be desirable that he undertake some degree of responsibility for work performed after regular working hours, e.g., emergency services.

During the second year of in-service training, the student would undertake projects in method development, method evaluation, quality assurance and control, and laboratory management, in addition to acting in a back-up supervisory capacity in those areas for which he had demonstrated a high degree of competence, including instrument maintenance, trouble-shooting and repair. The projects assigned should be of relatively short duration in order to provide a broad experience, and ensure that the student develops many of the skills required of a laboratory supervisor. During this second year the student should improve his teaching skills by involvement in staff and student training and continuing education programs.

Where certain techniques are not carried out in a laboratory, arrangements should be made for the student to gain experience in those particular techniques in another laboratory.

The in-service training program should specify regular involvement in certain clinical activities, such as ward rounds, case discussions and clinico-pathology conferences, to enable the post-graduate student to appreciate more fully the advantage of being an active member of the multidisciplinary clinical-care team. Another activity that will develop skills in interpreting laboratory data includes involvement in "reporting" laboratory tests. Where appropriate, additional clinical information should be sought to enable the laboratory results to be correctly interpreted in relation to the specific clinical setting.

Reading list

Students are expected to do both general background reading and undertake in-depth study of specific topics. The student should learn to look at a scientific article in a critical way and develop an ability to assess the validity of the results reported and their possible application to his own work. A list of books, journals and special articles currently in use in different countries has been compiled and is available on request from the Secretary of the Commission/Committee "(Note a)".

Examination requirements

Students will be required to pass written, oral and practical examinations and present satisfactory progress reports on their in-service training and project work in order to obtain the M.Sc. or post-graduate Diploma in Clinical Chemistry. Students should be encouraged to take certifying examinations in those countries where they are established. These usually require one or two years of practical experience in an approved clinical chemistry laboratory.

3. SYLLABUS

The syllabus provides a summary of the material considered to be essential for a two year post-graduate course in Clinical Chemistry. This should be used as a flexible guide for the development of a more detailed curriculum appropriate to the needs and resources available to a particular country. As it is recognized that in some countries responsibility for hematology and/or microbiology or toxicology is undertaken by the clinical chemistry service, it would be expected that the relative emphasis on these subjects will vary

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according to local practice. The development and implementation of a training program based on the proposed guidelines should be undertaken by a local or national faculty.

The curriculum should be developed around a didactic program consisting of lectures, tutorials and informal practical teaching sessions in the laboratory. Some of the topics might be dealt with by visiting lecturers or visits to other training centres.

The subject material for the proposed post-graduate course is organized under the following headings:

3.1 General laboratory procedures
3.2 Techniques and principles used in clinical chemistry
3.3 Instrumentation
3.4 Analyses
3.5 Special projects
3.6 Clinical biochemistry
3.7 Clinical medicine
3.8 Laboratory organization and management

3.1 General laboratory procedures

The following procedures are considered to be essential to the operation of a routine service clinical chemistry laboratory. Most of these procedures will be learned through practical experience during in-service training supplemented with informal teaching, demonstrations and selected reading.

Specimen collection, preservation and preparation for analysis; constituent stability; documentation and sample flow systems.

Laboratory statistics: concepts of reference values and biological variation; confidence limits, t-test, F-test, X^2-test, regression analysis, non-parametric tests, precision, accuracy.

Chemical arithmetic, e.g., molar solutions, molar absorption, pH calculations, radioactive decay, isotope dilution.

Internal quality control, external quality assurance, quality assurance, reference methods, control of non-analytical aspects of laboratory procedures.

Quantities and units: conventional and SI units - conversion.

Laboratory requisitions and reporting systems including data processing and use of computers-laboratory records, workload statistics - legal aspects.

Reagents and apparatus: sources of supply, cost analysis, techniques for assessing quality of reagents and kits.

Materials for control of precision and accuracy: sources of supply, techniques for assigning appropriate values.

3.2 Techniques and principles used in clinical chemistry

It would be expected that most candidates would have some undergraduate exposure to many of the topics listed here. Instruction should be provided to ensure theoretical and if necessary, practical knowledge.

General techniques: preparation, purification and storage of reagents and solvents; solvent extraction, selection of buffers, dialysis, filtration and ultra-filtration, concentration; preparation of derivatives, preparation of protein-free filtrates.

Chromatography: various supporting media, e.g., paper membranes, gels, thin layer, ion exchange resins; gas liquid chromatography and high performance liquid chromatography.

Electrophoresis: conventional one and two dimensional electrophoresis: various supporting media.

Photometry, spectrophotometry and fluorometry: techniques of analysis by visible, ultra-violet, infra-red and fluorometric procedures. Applications in clinical chemistry.

Enzymology: methods of estimation of enzymes and isoenzymes (fixed incubation and kinetic methods). Units, standardization, stability.

Immunochemical assay: immunodiffusion, immunoelectrophoresis, competitive binding techniques, radioimmunoassay, EMIT, ELISA and receptor assays.

Radioisotopes: general principles; counting techniques; safety aspects and legal requirements for use and disposal. Applications and procedures in diagnostic tests (radioimmunoassay).

Microchemical analysis: experience with small sample and reagent volumes (pediatric clinical chemistry).

3.3 Instrumentation

The following instruments and apparatus are considered to be essential for operation of a routine clinical chemistry laboratory. Candidates should understand the theoretical and practical aspects, be able to set up and operate the equipment, trouble-shoot and perform minor repairs. They should be able to establish the correctness of calibration of the instruments and have knowledge of their applications and limitations.

General laboratory equipment such as centrifuges, water baths, balances, microscopes, pipetting devices, automatic dispensers.
Water purification systems - stills, de-ionizers, methods of checking and monitoring water quality.
Spectrometric instruments - absorption, flame emission, atomic absorption spectrometers and fluorometers.
pH meters.
Blood gas apparatus.
Electrophoresis and chromatographic equipment.
Gas and high performance liquid chromatographic equipment.
Continuous flow analyzers and discrete sample analyzers.
Electrometric titrators.
Kinetic analyzers.

The instruments and apparatus listed are in common use, but not necessarily found in all laboratories. To gain experience with instruments not available in the assigned training laboratory, arrangements should be made for the student to rotate to a hospital laboratory where such instruments are routinely used.

3.4 Analyses

Listed below in alphabetic order are some of the components commonly examined in an appropriate biological fluid (e.g., serum, plasma, cerebrospinal fluid, etc.) in a routine service laboratory. The student should be familiar with the theoretical principles of various methods used for measurement of these components and be competent in the performance of the particular method employed in the laboratory to which he is assigned. The student should also be familiar with the procedures employed for selection and evaluation of methods, not only for precision, accuracy, speed, simplicity, cost, etc., but also for sensitivity and specificity. This obviously relates to the selection of tests for specific clinical purposes and the assessment of the medical usefulness of tests.

Acid phosphatase
Alkaline phosphatase
α-Amylase
Alanine aminotransferase
Albumin
Aspartate aminotransferase
Barbiturate
Bilirubins
Bilirubin esters
Calcium
Carbamide
Carbonate + carbon dioxide
Carbon dioxide (pCO_2)
Catecholamines
Chloride
Cholesterol and esters
Coproporphrin (I + III)
Cortisol
Creatininium
Digoxin
Dioxygen (pO_2)
Diphenylhydantoin
Estrogens
γ-Glutamyl transferase
Glucose
Hemoglobin
Hydrogen carbonate ion
17-Hydroxycorticosteroid
Hydroxymethyl mandelate
Iron (II + III)
Lactate dehydrogenase
Lithium ion
Magnesium
Osmolality
17-Oxogenic steroid
17-Oxosteroid
pH
Phosphate (P)

Porphobilinogen
Potassium ion
Protein
Salicylate
Sodium ion
Thyroid stimulating hormone
Thyroxine
Transferrin
Triglyceride
Triiodothyronine
Urate
Urobilinogens
Uroporphyrin (I + III)

In addition, many laboratories will carry out procedures for the analysis of urine and stools, and for the assessment of gastric secretion, serum proteins by electrophoresis and for the assessment of pregnancy.

3.5 Special projects

Short-term projects involving a considerable number of the skills required of a laboratory supervisor (analytical, instrumental, evaluative, managerial, organizational) should be undertaken to encourage initiative and independence. The student should acquire an ability for clear report writing.

3.6 Clinical biochemistry

Candidates should acquire a general knowledge of the interpretative aspects of clinical biochemistry. A central course of lectures should be developed which integrate analytical chemistry and biochemistry with physiology and physiological chemistry. Case histories selected to illustrate biochemical derrangements in disease states should be integrated with the main course to give the student an opportunity to develop skills in the interpretation of laboratory results. These sessions should also relate to the selection and evaluation of tests and their medical usefulness.

It is suggested that the course in clinical biochemistry should include a general treatment of the topics listed below. The diagnostic tests listed in section 3.4 provide a general indication of the extent of coverage of the topics selected. More detailed guidelines are available from the Secretary of the Commission/Committee, on request.

Water and ionic balance
Renal function
Acid-base metabolism
Carbohydrate metabolism
Plasma proteins
Lipids and lipoproteins
Gastro-intestinal function
Liver function
Calcium, phosphorus and magnesium metabolism
Endocrine function
Common hereditary disorders
Nutrition
Purine metabolism
Clinical chemistry of pregnancy
Heme and porphyrins
*Hematology and coagulation
Clinical enzymology
Clinical pharmacology and pharmacokinetics
Toxicology

*The student should acquire a basic understanding of the general principles of hematology and blood coagulation. In countries where hematology is a responsibility of the clinical chemist, however, considerably greater emphasis on this component of the course will be required.

3.7 Clinical medicine

The science graduate entering clinical chemistry should seek every opportunity to familiarize himself with the relevant aspects of clinical medicine in order to communicate effectively with the medical staff. Knowledge about clinical medicine is also important for the medical graduate coming directly from the medical school. The supervisory staff should include a medically qualified clinical chemist if available. If not, satisfactory alternative arrangements will need to be made.

3.8 Laboratory organization and management

Laboratory safety: Mechanical, electrical, chemical, biological, fire and radiation hazards.

Laboratory work flow: Planning for efficiency; work flow and communication systems.

Budget: Preparation and monitoring.

Workload: Data processing (manual and/or computer).

Quality assurance: Implementation, monitoring and performance evaluation.

Technical staff: Education, training, performance assessment, work assignment.

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