

# Demand and Cultivation of Professional Talents in Clinical Engineering at Home and Abroad Based on the Analytical Theory

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**Abstract**—With the development of medical technology, medical equipment is increasingly complex and the professional application of medical equipment continues to increase. However, due to the lack of knowledge in medical engineering for medical staff, the function of equipment can not be fully developed, restricting the efficient utilization of medical equipment. However, the clinical engineers with engineering technology background can promote the use of medical equipments. This article will combine the history and present situations at home and abroad to analyze the job responsibilities and professional development needs of clinical engineers, put forward the training mode of professionals in this field, and focus on the application of the engineering field in medical clinic to develop core knowledge and training methods for clinical engineering profession and provide suggestions for the cultivation of clinical engineering professionals.

**Keywords**—*Clinical Engineering; Professional Talents; Talent Demands; Talent Training*

## I. INTRODUCTION

With the development of natural science such as physics, chemistry, biology and information, the dependence of medical science on engineering is becoming more and more obvious. According to the experience and development model of the developed countries in the world, the biomedical engineers need not only understand the medical equipment, but also have to master the relevant medical knowledge to become the clinical engineers with both the medical and engineering knowledge. At the same time, with the constant improvement of living standards, the requirements for the safety, effectiveness, and ethicality of medical services continue to increase, while the traditional health care team structure and knowledge reserves cannot meet the needs of the existing medical services. Clinical engineers are professionals who support and promote patient treatment by applying management skills in the field of medical technology to ensure the professionalism of medical equipment use, the maximum development of the equipment's use function and the quality safety. Therefore, the clinical engineering post plays a more and more important role in the medical activities, the corresponding professional talent training is still at the primary stage in our country, and the corresponding standardized talent training program is not yet mature. Such situation highlights the situation that does not match the talent demand.

## II. DEFINITION OF CLINICAL ENGINEER

In the 1970s of last century, the career concept of clinical engineers was firstly proposed and hospitals at all levels gradually established the medical engineering department, the main tasks of which are to ensure the clinical application of medical equipment business and improve the safety and reliability of medical equipment. Its main post responsibilities include pre-purchase evaluation and inspection, incoming inspection and quality control of medical equipment, daily management, maintenance, repair and operation training after installation and acceptance, as well as the demonstration and verification work of equipment scrapping. In the hospital management of Europe and the United States, the Department of Medical Engineering, the Medical Service Department, and the Department of Nursing maintained a tripartite collaboration situation, while providing high-quality effective medical services at high speed [1].

## III. STRUCTURES OF CLINICAL ENGINEERING DISCIPLINE

With a large number of advanced medical equipments entering hospitals, the continuous improvement of technological contents of medical equipments, and the increasing complicated application complexity, in particular some life support equipments such as ventilators, artificial heart-lung machines and other equipments, the high degree of specialization and complex operation, the safe use of equipment becomes a new challenge for medical staff without engineering backgrounds. For such equipments, hospitals have successfully established medical engineering departments, and some hospitals have also set up clinical engineer posts to ensure the safety of the equipment. However, clinical medicine engineering is after all a new discipline. Compared with other medical science specialty, the establishment time is shorter, the number of personnel, as well as the academic and technical quality and the level are uneven. There exist the requirements of engineering team construction and medical engineering technology development, the high requirements of the technical level of engineering technicians and the medical equipments, as well as the condition that the integration of science, technology, and medicine are not suitable for the requirements of science and technology. The clinical medicine project occupies an irreplaceable position in the hospital, but how to develop and how to combine with medicine is still a problem to be solved urgently.

According to the requirements of clinical engineering post and the law of talent training, the technical personnel of the clinical engineering are professional technicians who are familiar with the clinical medical application with the knowledge of science and technology. The requirement of personnel training should be the organic combination of clinical medicine and engineering technology, namely, using the engineering technical means to solve the clinical problems, and taking into account the problems of medical safety, medical ethics, etc. in the process of implementing the engineering operation. The tasks of medical engineers are to solve the new clinical needs and problems in combination with the medical knowledge such as clinical medicine, nursing and rehabilitation, with the background of engineer-related engineering knowledge. This not only promotes the development of medical science, but also promotes the construction of medical engineering disciplines, and the characteristics of medical engineering disciplines will also be reflected in this combination.

At present, the main tasks of clinical medical engineering are the medical equipment management, security, scientific research, teaching, hospital engineering and main operation guarantee. Management of medical equipment includes planning, supply, use, maintenance management and measurement. The management and maintenance level of medical equipment is the technical intensive work, the technology is complicated, and the professional work is also very high. This will involve various new technologies and new methods of medical equipment and other natural disciplines. There are two aspects of the problems faced by clinical medical engineering. On the one hand, it is how to cooperate with the medical staff with the engineering thinking to carry out the functional development and technical guarantee of the existing medical equipments so as to give full play to the

clinical function of the medical machinery. On the other hand, it is to combine the problems in clinical practice to select scientific research subjects, including the transformation of medical problems and physical models, equipment innovation and development, as well as the development and application of new technologies so as to achieve the purpose of improving and enhancing clinical diagnosis and treatment techniques and better serving the patients. It is a realistic task and a long-term goal, and is also the most important means for achieving the integration of science, engineering, and medicine.

#### IV. OCCUPATIONAL CONTENT AND SKILL REQUIREMENTS OF CLINICAL ENGINEERS

In the United States, the concept of clinical engineering (CE) for the purpose of comprehensive management of the ME (Medical Engineering) instrument began in the middle of the 1960s and established clinical engineering departments in several hospitals. In 1968, a system for appraising clinical engineering technicians was developed in a timely manner in the AAMI (Association of Advancement of Medical Instrumentation). The system is still continuing at present and is the backbone of the American clinical engineering system[2].

Currently, in the hospitals of the United States, the clinical engineering department is the organization which must be established in the hospital. Its main tasks are to take charge of the instrument of the comprehensive hospital, from the procurement plan of instruments and selection of models to acceptance, training of operators, routine maintenance, periodic inspections, fault diagnosis and maintenance. The staff responsible for the above tasks is the clinical engineer (CE) and the Bio-medical Equipment Technician (BMET). The specific differences are shown in Table 1:

TABLE I. TYPE AND BUSINESS CONTENT OF CLINICAL ENGINEERS (CE) IN THE UNITED STATES

Formal Name	Abbreviation	Post Contents(Example)
Clinical Engineer	CE	Equipment management (medical equipment planning, evaluation, procurement, acceptance, filing, technical research, technical training and consultation, etc.)
Bio-medical Equipment Technician	BMET	Maintenance operation (equipment operation, routine maintenance, quality control, fault maintenance, functional development, etc.)

Based on the above post requirements, the AAMI of the United States stipulates in the examination guide that the clinical engineer should use the knowledge of the technical engineering system to give full play to the performance of the medical equipment through the use, maintenance and management of the medical equipment and ensure the safety and effectiveness of the medical equipment. It is essential for the clinical engineer to have the following qualifications: 1. Contact the surgeon, the hospital leader and the medical service personnel by applying the engineering method; 2. Have relevant professional knowledge reserves in many engineering fields, such as electronics, machinery, computers, etc.; 3. Have the support of relevant knowledge and projects in physiology, medicine, health care and so on required by the

investigation and treatment of medical accidents; 4. Have the knowledge of medical instrument regulations, standards and equipment management, and can provide medical equipment configuration and evaluation opinions based on the engineering; 5. Be familiar with medical equipment and can carry out equipment operation training and technical display on its function; 6. Understand medical ethics and have professional ethics and conscientious professional consciousness.

The clinical engineer shall implement the qualification examination system, and the person who takes the exam shall generally have one of the following conditions: 1. Have a bachelor's degree or above in Engineering or Electronic Engineering University, and more than 3 years working

experience in clinical engineering; 2. Have already owned the qualification of engineers with over 3 years working experience in clinical engineering area; 3. Have already owned a bachelor's degree in basic sciences in non-engineering or electronic engineering, with more than 4 years working experience in clinical engineering; 5. Have undertaken clinical work more than 15 years, including more than 5 years in leadership positions. Have working experience related to equipment management and maintenance. The qualification assessment contents of clinical engineering personnel involve two aspects including the clinical and engineering. Clinical aspects mainly involve: clinical overview, human anatomy physiology, pathology, nursing, etc. Engineering aspects involve: engineering foundation, equipment maintenance, policies and regulations, management foundation, etc [3].

#### V. TRAINING MODE OF CLINICAL ENGINEERS

The cultivation of clinical engineers is based on traditional engineering education combined with physiology, ergonomics, system analysis, medical terminology, metrology, as well as instrument and equipment principle. Clinical engineering is an interdisciplinary and multidisciplinary application specialty, which poses many challenges to curriculum setting and coordination. The education and training content of such profession should take into account the problems and methods that should be solved in the actual work of clinical engineers, and should be carried out in complex human systems and technical systems. As more and more clinical engineers participate in the clinical work of the hospital, they play a multifaceted role. They must successfully contact many people, including medical staff, hospital management personnel, regulatory agencies, etc., to ensure the safe and effective use of hospital medical equipments [4].

The training objective of the clinical medical engineering specialty is to ensure that the clinical diagnosis and treatment are safe and effective and the results of engineering technology are better served in clinical medical care. Thus, the

full technical management of medical equipment developed in hospitals is the main task, to solve the problems of technology, equipment and economic management in the modernization of hospital equipment, and its workplace is in the hospital. The main work contents include: procurement and supply of medical equipment (including medical machinery), management and maintenance, optimization of configuration, quality control, information processing and utilization; system integration, management and maintenance, optimization of configuration; equipment and system applications. At present, the setting of clinical medical engineering curriculum is mainly based on the principles and systems of various medical instruments, such as medical sensors, medical ultrasound, hospital charging system, and the registration system. However, in the actual clinical work, the systems used by us are all integrated by various equipments and systems. In the integration process, new problems may be introduced, such as the mutual matching between equipments. Therefore, in the teaching process, we should make the students recognize the concept of system integration and make teaching more clinical. Thus, the content of the lectures should cover: mathematics, physics, chemistry, biology, management science, and engineering science. Many traditional engineering is the foundation of clinical engineering, such as mechanical engineering, electronic engineering, chemical engineering, and computer engineering; Life science courses usually include: biochemistry, biology, physiology, and anatomy, etc.; The multidisciplinary combination of engineering and life science is a unique combination of clinical engineering and other engineering science. Professional courses can be divided into the following major categories: medical instruments and image processing, including circuits, digital image processing, sensors, etc.; microcomputer principles and applications, including microcontrollers, computer principles and applications, medical information systems, etc.; Basic medical science including systematic anatomy, physiology, etc.; Biomedical engineering professional courses, including biomechanics, biomaterials, medical sensors, etc. Specific curriculum settings are shown in Table 2:

TABLE II. CLINICAL ENGINEERING CURRICULUM SETTINGS

Basic Course	Engineering Course	Medical Course	Humanity Course
Mathematics, physics, chemistry, etc.	Electronic technology, control technology, machinery manufacturing, computer technology, biomedical detection, etc.	Human anatomy, Human physiology, pathology, diagnostics, etc.	Medical related regulations, medical device related regulations, medical ethics

Based on the application of talent training, the teaching method should adopt the model of integration of theory and practice, and the principle part of relevant curriculum should be mainly based on enough use and consider the wide range of conceptual applications. For example, physical concepts related to all medical equipments should be covered as much as possible in the physical course, such as ultra-generation technology, optical technology, nuclear magnetic technology, etc.; In the part of professional courses, more problem-oriented teaching methods should be adopted, such as putting forward some technical problems in the clinic, and proposing

the corresponding engineering solutions through guidance; In the courses concerning humanities, focus should be given to industry-related laws and regulations. Because of the particularity of medical industry, relevant laws and regulations are highly professional and compulsory, and the learning of relevant knowledge will provide legal guarantee for future work. At the same time, the humanistic curriculum should also take into account the relevant contents of medical ethics, so as to ensure the ethical problems of traditional Chinese medicine in the process of providing the clinical services.

## VI. CONCLUSION

The development of clinical engineering talents aimed at improving the quality of medical services is also influenced by many factors such as policy support, institutional guarantee and so on in addition to taking into account the problems of multidisciplinary collaborative development. To do well in the development of clinical engineering discipline and benefit the clinic, it still needs many efforts and co-propulsion. Besides, with the constant development of medical technology, the continuous improvement of medical quality required by the clinic, as well as the constant refining of the clinical department, the classification of clinical engineering technology corresponding to it is also continuously refined, which poses a new problem for the development of clinical engineering disciplines. How to better serve the clinic and refine the sub-discipline classification of clinical engineering will be the research direction at the next step.

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