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Improvements in Clinical Laboratory Techniques, Technologies, and Practices with A Focus on The Equipment and Personnel: A Consolidated Review

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Key words: Medical laboratory Science (MLS), Medical laboratory technology, Clinical medical inspection, Diversity of education, Clinical inspection center

ABSTRACT

Background and aims: In recent years, exquisite diagnostic techniques are stringent demands in medical laboratory science (MLS). The review discusses ways to improve clinical laboratory techniques under the current level of medical care in China.

Materials and methods: With a focus on China's current situation and development direction of clinical detection technology, journal literature was reviewed, and reforms in the educational concepts were studied. Herein, reforms in the management practices of clinical medical testing departments as well as the development and production status of medical testing instruments are discussed.

Results: Medical schools should change the educational concept from the traditional "indoctrination" teaching method to a diversified teaching method. Hospitals should strengthen the daily management of laboratories and improve the professionalism of laboratory personnel. The government should strategically set up regional inspection centers to provide medical inspection services for small hospitals at the township and community levels. Manufacturers should be encouraged to develop and produce advanced instruments to continuously improve the efficiency and accuracy of the instrumental test results.

Conclusions: Diversity teaching methods in high medical schools, daily management improvement of laboratories, and government support will cultivate excellent medical laboratory personnel, and improve clinical laboratory techniques.

1. Introduction

medical laboratory science encompasses the fields of microbiology, immunology, biochemistry, genetics, hematology, biophysics, and cytology, and involves the inspection of materials derived from the human body. It provides information to clinical physicians for the prevention, diagnosis, and treatment of human diseases, as well as the health assessment of people participating in clinical treatment activities. Medical laboratory technology is a significant independent part of MLS. It involves the technology and skills to perform laboratory inspection of specimens such as blood, body fluids, secretions, or exfoliated cells from patients to obtain information on pathogenic and pathological changes, as well as the functional state of organs [1]. It an important branch of medicine, mainly focusing on the experimental operation (methods, principles, inspection of analysis results), providing laboratory technicians (technologists) for research institutes and laboratories. There are several disciplines encompassing medical microbiology (bacteriology, parasitology, virology, mycology), clinical chemistry (chemical pathology), hematology and blood transfusion science, histopathology, forensic science, molecular biology, laboratory management, and other related fields [2]. The field of clinical medical examination technology directly affects clinicians' diagnosis and treatment of patient conditions. Scientific, rapid, and accurate medical examination can greatly improve the level of clinical diagnosis and treatment and grant more treatment opportunities. To a certain extent, the progression of this discipline is closely related to the progressiveness of clinical medicine. Modern clinical medical inspection is of great significance to clinical diagnosis and treatment activities. Understanding the status and application of modern clinical medical inspection technology can effectively improve the quality of clinical medical inspection, enrich the doctors' own knowledge, and promote the development of clinical medical inspection work.

2. Current situation and development direction of clinical testing technology

Automation is one of the most significant developments in clinical detection technology. In the past, clinical testing technology relied on manual work. For example, malaria is mainly diagnosed in clinical laboratories using blood smear microscopy, which is still widely used in Ethiopia [3]. In the semi-automatic stage, because of the inefficiency of manual inspection, the results can be readily altered owing to operational errors and other external factors, resulting in inaccurate detection results and consequently affecting the clinical treatment. With the development of computerized testing technology, automated equipment is used for inspection, and the examination is conducted swiftly and accurately, which considerably minimizes the error in the test results obtained from manual operations. Various types of immune cells and pathogenic bacteria can be tested for diseases. Therefore, the automation of this process can significantly improve the effectiveness and efficiency of clinical examinations. Their accuracy has also significantly improved, providing valuable information for disease prevention, diagnosis, and treatment. For instance, immunolabeling techniques have been widely used with the added advantage of high sensitivity, leading a broad range of applications in clinical treatments.

Additional testing technologies have been applied in clinical testing. For example, next Generation Sequencing (NGS) technology has become an integral in clinical diagnosis [4]. Radioimmunoassay (RIA) and enzyme immunization (EIA) technology [5, 6] have further improved the accuracy of clinical testing, expanding the scope of application of the testing technology and providing greater convenience to the patients.

3. Education for clinical laboratory medicine students in medical schools

3.1. Traditional education model

Improvements in medical testing technology are fundamental to the skill enhancement and quality training of the testing personnel. How colleges cultivate excellent inspectors is closely related to teaching effectiveness. The traditional teaching method is the "indoctrination" method, where the syllabus and coursework distributed by the teachers is formulated solely by the school, to impart theoretical knowledge to students. Similarly, the laboratory class is mainly based on the teachers' explanation, the test type is mainly a confirmatory test, and there are few clinical laboratory internship opportunities. This teacher-centered method emphasizes theory, in which students learn solely through listening and rote memorization, and disregards practical clinical work. This form of education not only has a low teaching effect but also fails to provide students with opportunities for independent thinking and innovative experimentation. Hence, a large gap exists between theoretical concepts and clinical laboratory practices [7]. To guarantee the progression and advancement of this discipline and cultivate applied talent, college education needs to urgently reform its traditional teaching methods.

3.2. Diversified teaching model

Presently, higher education has started to change its educational thinking, adopting a diversified teaching model, transforming traditional lecture methods into student-centered ones, which allow students to actively participate in the classroom and solve problems on their own through independent thinking and group collaboration [8] This way of teaching can greatly stimulate students' enthusiasm for learning and enhance their thinking and innovative ability. Additionally, college education has begun placing emphasis on practical teaching [9]. Clinical detection science emphasizes both theory and practice. Clinical internships are an important opportunity for laboratory medical students to apply theoretical knowledge to practice. Thus, internship teaching is a sublimation of theoretical teaching, and is essential in the cultivation of excellent laboratory medical skills. Internship teaching includes teaching purpose, training, skill handling, and the assessment of medical students. Emphasis on practical teaching can also combine theoretical knowledge with practice and enhance the ability of test operations, resulting in a more profound understanding of theoretical knowledge. The effect of teaching and learning can be achieved through diversified classrooms, internship teaching, questionnaire surveys, teacher–student mutual evaluations, and other assessment methods.

3.2.1. Computer virtual simulation teaching platform

With the rapid development of computer and network technology, virtual simulation teaching platforms play an increasingly vital role in the training of medical laboratory personnel [10]. Using morphological maps, 3DMAX, or flash animations, the platform integrates graphics, text, and audio, immersing students into clinical teaching content that includes fundamental and challenging problems of medical technology science [11]. It cultivates a "self-discovery and self-exploration"- style of learning, greatly promoting the effectiveness of this teaching method [12].

3.2.2. Teaching of problem-based learning (PBL) and case-based learning (CBL) methods

The PBL method was first proposed by Barrows, an American professor of neurology, at McMaster University in Canada in 1969 [13]. The PBL method is a student-centered and problem-oriented method of teaching. Teachers encourage students to explore different problems and allow them to solve a series of complex problems on their own. This can promote students' subjective initiative, stimulate their innovative thinking ability and collaborative ability, and help them understand the teaching content in depth. Fan et al. [10] showed that the practice effect in a PBL teaching group was significantly enhanced compared to that in a traditional teaching group. The CBL method focuses on improving students' competence in laboratory medicine. Li et al. [14] found that among 107 medical laboratory medicine intern volunteers, in the control group of teacher-centered methods, students in the CBL teaching program had significantly higher theory test scores and skill assessment scores on average. Noticeable improvements included recognizing and processing instrument alarm messages, analyzing test results, identifying and resolving problems, and identifying and reporting critical values and clinical communications. The questions raised were in the context of real cases in this course of "problems" combined with "cases," in which the students were the focus. The aim was to motivate students to discuss the problem while cultivating their clinical thinking through handling real clinical cases on their own. Thus, PBL and CBL methods are worthy of promotion in laboratory medicine teaching [15, 16].

3.2.3. Mini-Clinical Evaluation Exercise (Mini-CEX)

The Mini-CEX is a set of tools recommended by the American Board of Internal Medicine in 1995 to evaluate the clinical skills of residents with teaching and evaluation functions [17], which has been applied in standardized physician-training assessments and other fields [18, 19]. Mini-CEX assessment focuses on seven major indicators: medical interview, physical examination, humanistic care, clinical judgment, clinical consultation, organizational effectiveness, and overall performance. The assessment is conducted by an instructor (assessor), an intern trainee, and a co-consultant patient in a suitable time and place to focus on clinical behavior within 15–20 min; then, the instructor gives a score and 5–10 min feedback after directly observing the trainee's interaction with the patient [20, 21]. As a formative assessment, the Mini-EEX rating scale is used to assess the outcome-based student assessment (OBSA) learning evaluation method in basic medical laboratory course (BMLCs) curriculum practices, in which Mini-EEX is modified from the mini-clinical evaluation exercise Mini-CEX [22].

3.2.4. PDCA cycle teaching

PDCA, also known as the quality loop or Deming loop, is a set of scientific procedures for total quality management proposed by Dr. Deming, an American quality management expert, in 1954 [23, 24]. PDCA consists of four links: Plan, Do, Checking, and Action, which have gradually been introduced into teaching management in select medical schools in recent years [25]. Gu's research showed that the application of the PDCA cycle in clinical teaching activities can improve the teaching process during the outbreak of coronavirus disease 2019 (COVID-19) and produce more competent clinical interns compared to those in the control group adopting traditional teaching methods [26]. In the Leitmann study, the evaluation of the subjective questionnaires indicated that the 25 students achieved a higher subjective increase in performance and learning success in the PDCA groups than in the Peyton-Group [27].

This PDCA teaching system of mutual evaluation and feedback between teachers and students can greatly mobilize the subjective initiative of interns so that they can actively discover problems, consult materials, and improve their ability to think independently and solve problems, as well as significantly stimulate their interest in professional learning. At the same time, through the feedback of the intern satisfaction questionnaire, teachers can quickly discover the deficiencies in the class, dynamically improve the clinical teaching program, and enhance the overall quality of their teaching methods.

3.2.5. Blended learning (BL) model

Online courses are becoming popular in today's education system in the era of big data, especially since the outbreak of COVID-19 in Wuhan, China. Web-based curriculums offer medical educators the opportunity to expand their teaching methods. BL, defined as '*a combination of online and in-class instruction with reduced in-class seat time for students*' [28] by the U.S. Department of Education, is an integration of in-person classes and online instruction [29], is widely adopted across higher education institutions, and is considered as the 'new normal' in course delivery [30].

Massive Open Online Courses (MOOCs) are large-scale online courses. They were first introduced at the University of Manitoba in 2008 with "Connectivism and Connective Knowledge" [31]. The online platform optimizes and integrates a variety of learning resources such as videos, lecture notes, and after-class exercises, and is openly shared. It overcomes the limitations of time and space, enabling real-time interaction between teachers and students, without the distance barrier. Lecturers are reputable experts, providing the most innovative ideas in their respective field, which can broaden the students' horizons. Using a variety of MOOCs, students can select suitable videos to improve their learning efficiency [32]. Donkin et al. [33] found that students who participated in online video courses had statistically better practical examination scores and final grades compared to the control group.

4. Establishment of a clinical inspection center

With the growth of the aging population, the change in the public's way of life, and the evolution of human diseases worldwide, medical resources have become scarce and are unevenly distributed in most countries, particularly in those with large populations. Surveys show that primary medical institutions serve approximately two-thirds of the population's medical and healthcare work in China [34]. However, medical inspection capabilities are severely limited because of outdated equipment and uneven personnel capabilities in these institutions. In contrast, state-of-the-art diagnostic instruments are mostly concentrated in large tertiary care hospitals, which in turn causes the status quo of expensive and exclusive medical treatment. Balancing the distribution of medical resources, standardizing the level of testing personnel, and providing guarantees for the earliest treatment of patients are current difficulties faced by medical services. On February 28, 2017, the National Health and Health Commission issued "Determination on Amending the Implementation Rules of the Regulations on the Management of Medical Institutions" (Order No. 12 of the National Health and Family Planning Commission). Subsequently, third-party clinical medical testing laboratories received government policy support and universal recognition from the capital market. Therefore, several clinical testing centers (also known as regional clinical testing centers) attached to large hospitals have been established in rapid succession, such as the Clinical Testing Center of the Municipal Medical Group formed by the Department of Laboratory of the People's Hospital of Maanshan City, Anhui Province, and the regional clinical testing center formed by the Department of Laboratory of the Songjiang District Central Hospital in Shanghai. These inspection centers have many automated instruments and these are used in teaching and research tasks. The centers have applied the technology for efficient and refined management, established big data files, facilitated digital logistics for specimen transportation, realized data monitoring and sharing within the region, optimized inspection processes, and improved inspection quality.

5. Encouraging the development of inspection equipment enterprises

Increasing electrification and automation in modern society has made it possible for clinicians to use highly sophisticated medical equipment to accurately diagnose and treat diseases. Through the support of policies and taxes, the government can improve the comprehensive market competitiveness of medical equipment manufacturers and encourage research on and development of better equipment [35]. According to the report, the market size of China's medical device industry reached 525 billion Yuan in 2018, an 18% increase compared to the previous year. The compound growth rate increased by 20% between 2013 and 2018 [36]. It is worth noting that medical equipment requires regular maintenance for optimal functionality.

Hence, traditional enterprises must continue to transform and upgrade their products to fulfill the urgent need for medical device development. In some county hospitals, the focus is on improving the proportion of inspection equipment and medical laboratory efficiency.

6. Conclusion

The task of clinical laboratories is to provide reliable information for the detection, diagnosis, prognosis, prevention, and treatment of human diseases. Therefore, it is paramount that clinical laboratories employ the latest and most appropriate analytical methods for the detection of chemical species in biological fluids. Many teaching and clinical experiences show that various factors affect basic clinical medical detection techniques. For example, subjectively, laboratory personnel must have a high degree of professionalism and responsibility; objectively, colleges should actively improve their teaching modes to optimize the training of medical personnel in laboratory medicine. There should be a "double-qualified" teacher team to guide students in transforming ideas from theory to clinical practice. The hospital laboratory department should implement regular training and assessment of laboratory personnel, strengthen the daily management of the laboratory, and pay attention to the handling and storage of specimens, thus improving the quality of rigorous and scientific testing by staff. Hospital leaders should value research posts, strive to improve the level of scientific research, and accelerate the transformation of clinical medical inspection results. The accuracy and advanced degree of the inspection instruments must have advanced hardware. Furthermore, the government and hospitals should increase policy support for laboratory departments and manufacturers of medical testing equipment. Although deficiencies still exist in the basic testing technology of clinical medicine in China, it is believed that further improvements will be achieved through constant development.

7. Author Statement

Meiling Zhou and Yuming Yao have equal contributions to this article.

8. Conflict of Interest

The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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10. Highlights

1. Medical laboratory science (MLS) is an important independent branch of medicine education system.
2. Clinical laboratory techniques is significantly important to clinical works.
3. Students majoring in MLS should master the basic theoretical knowledge and experimental operation skills of clinical laboratory medicine (CLM).
4. Diversified teaching method is proved to enhance students' integrative competence, including clinical laboratory techniques.

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