An Innovative Teaching Approach for Diabetes Mellitus in Laboratory Medicine Uses the Clinical Laboratory Diagnostic Pathway

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ABSTRACT

OBJECTIVES: The routine teaching mode of diabetes mellitus (DM) is divided into various sub-majors of medical laboratory, which is not conducive to clinical laboratory physicians quickly mastering relevant knowledge. A novel DM laboratory testing pathway is established to improve teaching efficiency and enhance the effects of talent cultivation in laboratory medicine.

METHODS: The guidelines and expert consensuses of DM were gathered from professional websites and databases. The clinical laboratory diagnostic pathway was formulated, and the questionnaire and mutual evaluation were used to evaluate the teaching effectiveness of 8-year undergraduate students enrolled in 2018 and enrolled in 2019, respectively.

RESULTS: Clinical laboratory physicians developed and approved the DM clinical laboratory diagnostic pathway, which included the entire process of DM diagnosis and differential diagnosis, drug selection, treatment impact monitoring, prognosis evaluation, etc. The results of the questionnaires showed that, in comparison to the teaching mode used with the students enrolled in 2018 and enrolled in 2019, the percentages of more improvement and significant improvement were significantly increased ($P < 0.01$) and the percentages of no improvement and slight improvement were significantly decreased ($P < 0.01$). Following the instruction of the DM clinical laboratory diagnostic route, the results were greatly improved, including points emphasized and the accuracy of responding to questions, among other things, according to the teachers' and students' mutual evaluation ($P < 0.05$).

CONCLUSIONS: To enhance the teaching quality in laboratory medicine, it is required to build the disease clinical laboratory diagnostic pathway for a novel teaching method. This may boost teachers' and students' confidence and broaden their knowledge.

KEYWORDS: Clinical laboratory diagnostic pathway, diabetes mellitus, laboratory medicine, teaching mode

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Introduction

Diabetes mellitus (DM) is a complicated chronic disease caused by absolutely or relatively insufficient insulin.[1] The number of patients with diabetes rose from 108 million in 1980 to 463 million in 2019.[2] The prevalence of DM in low- and middle-income countries increased faster than that of high-income countries. The main complications of DM include blindness, kidney failure, heart attack, stroke, and lower limb amputation.[3] As a result, the prevention of DM and the reduction of complications are of great significance in the diagnosis and treatment of DM.[4]

Type 2 DM (T2DM) accounts for about 90% of diabetic patients, which needs continuous multiple measures for reducing risk factors as well as blood glucose.[5] Many interventions may change the outcome of diabetes, and continuous self-management is very important to prevent acute complications and reduce the risk of long-term complications. It indicates that simple lifestyle changes can effectively prevent or delay the onset of T2DM. For example, diet control, physical activity, medication, and regular screening and treatment of complications are beneficial for the therapy and outcome of diabetes. A healthy diet, regular physical activity, keeping a normal weight, and quitting smoking can prevent or delay the onset of T2DM.[6]

Many academic societies of diabetes around the world have put forward the goal of diabetes management: preventing

complications and optimizing the quality of life. They provide multiple suggestions for the prevention of DM.[7] The World Health Organization (WHO) will publish the "Global Diabetes Compact" in 2021, which aims to provide urgent impetus for DM prevention and provide therapy for all patients in need.[8]

As a matter of fact, separate courses, including clinical routine testing, biochemical testing, immunological testing, microbial testing, and molecular biological testing of laboratory medicine, are distributed in different chapters of this discipline.[9] As a result, it is difficult for students in clinical medicine or in laboratory medicine to gain a comprehensive knowledge of laboratory medicine. It seems complex for students to master the clinical significance of laboratory indicators comprehensively, especially for the relationships between different indicators and their role in the process of disease diagnosis and treatment.[10] Therefore, the DM clinical laboratory diagnostic pathway proposed in this paper aims to supply the evidence of clinical laboratory for the monitoring, treatment, and prevention of diabetes and to ease the early discovery of complications of diabetes, which will slow the progression of the disease. Appropriate use of clinical laboratory diagnostic techniques and dynamic monitoring of laboratory indicators that reflect disease progression and organs' function are of great significance for precise diagnosis and treatment, prognosis improvement, and the control of disease. At the same time, the novel teaching mode is based on the clinical laboratory diagnostic pathway and connects different sub-disciplines of clinical medicine into the diagnosis, therapy, prevention, and monitoring of DM. The advantages of the novel teaching mode will facilitate the panoramic learning of laboratory medicine for different diseases and also boost the continuous development of the quality of teaching in this discipline.

Materials and methods

Clinical practice guidelines or expert consensus for DM

The international guidelines for DM diagnosis and therapy include (1) Database: searching for the keywords "diabetes" and "guideline" or "expert consensus" in the PubMed database (https://pubmed.ncbi.nlm.nih.gov) or Google to get related guidelines; (2) Professional website of diabetes: International Diabetes Federation (IDF) (https://www.idf.org/e-library/guidelines.html), American Academy of Clinical Endocrinology (AACE) (https://pro.aace.com), American Diabetes Association (ADA) (https://www.diabetes.org), European Cardiology Society (ESC) (https://www.escardio.org), WHO (https://www.who.int), etc. Furthermore, the Chinese guidelines or expert consensus for DM mainly came from the database: searching for the keyword "diabetes," "guideline" or "expert consensus" in the Wanfang database (https://www.wanfangdata.com.cn) or China Network of Knowledge database (https://www.cnki.net) to gain related documents, and the testing standards in clinical laboratory came from such sources as the Clinical and Laboratory Standards Institute (CLSI) (https://clsi.org), the College of American Pathologists (CAP) (https://www.cap.org), etc.

The guidelines or expert consensus adopted in this study included the ADA Standards of Medical Care in Diabetes—2023,[11] Clinical Practice Guidelines of the American Society of Clinical Endocrinology: Application of Advanced Technology in the Management of Diabetes,[4] The guideline for Diabetes, Pre-diabetes and Cardiovascular Disease (2019)[12] developed by ESC and EASD, Screening for Gestational Diabetes: US Preventive Services Task Force Recommendation Statement,[13] KDIGO 2022 Clinical Practice Guideline for Diabetes Management in Chronic Kidney Disease,[14] Clinical Practice Guideline for Diabetes Management in Chronic Kidney Disease, Standards of Medical Care in Diabetes,[15] Standards of medical care for type 2 diabetes in China 2019,[16] Chinese Guidelines for the Clinical Diagnosis and Treatment of Diabetic Kidney Disease formulated by the expert group of the Nephrology association of Chinese Medical Association,[17] Expert consensus on early prediction and diagnosis of diabetic kidney disease,[18] Chinese Guideline for Diagnosis and Treatment of Diabetes in the Elderly (version 2021) formulated by the National Center for Geriatrics,[19] Guidelines for the rational drug use of type 2 diabetes at basic clinics formulated by the Chinese Medical Association,[20] Chinese Guideline for Type 2 Diabetes Prevention (version 2020) formulated by the Diabetes Branch of the Chinese Medical Association,[21] the Expert Consensus on Diabetes Remote Management (version 2020) formulated by the Diabetes Expert Committee of the National Telemedicine and Internet Medical Center,[22] Remission of Type 2 Diabetes: User's Guide: Diabetes Canada Clinical Practice Guidelines Expert Working Group,[23] and Consensus report: Definition and interpretation of remission in type 2 diabetes,[5] etc.

Extraction and analysis of the testing items for DM

The diagnosis and therapy process of DM can be divided into diagnosis, differential diagnosis, comorbidities, risk assessment, clinical decision of therapy, drug selection, prognosis evaluation, side effects and efficacy monitoring of drugs, recurrence monitoring, and complication treatment. All the related testing items in the clinical laboratory for the progression of DM were extracted and sorted according to the above guidelines gained and the order changes in disease progress.

Establishment and optimization of clinical laboratory diagnostic pathway for DM

Firstly, physicians in the clinical laboratory draft the clinical laboratory diagnostic pathway for DM, according to the testing items extracted from the progress of the disease.

Secondly, the draft was revised and improved after discussion with endocrinologists, nephrologists, and other physicians who are experienced in DM diagnosis and therapy. Thirdly, the revised and optimized clinical laboratory diagnostic pathway for DM would be applied in outpatient follow-up for patients with diabetes.

DM teaching mode using clinical laboratory diagnostic pathway

The research subjects of this study included all 8-year medical undergraduates enrolled in 2018 (44 persons) and enrolled in 2019 (46 persons) from the First Clinical College of Wuhan University. All of them were in the fourth academic year with the same teaching progress. The medical undergraduates enrolled in 2018 were carried out in routine teaching mode, while the ones of medical undergraduates enrolled in 2019 were applied in novel teaching mode based on clinical laboratory diagnostic pathway, and DM acted as an example discipline. This study was carried out during normal teaching activities. All teaching activities were conducted at the Department of Clinical Laboratory, Renmin Hospital of Wuhan University, which is an affiliated hospital of the First Clinical College of Wuhan University. The same online questionnaire and mutual evaluation between teachers and students were used to conduct timely evaluations after teaching. Two quizzes were conducted, each with a score of 100, to test the effects of learning key points from the lessons. *Inclusion criteria*: Those who participate in the entire teaching activity and at least participate in one of the online questionnaire, mutual evaluation included student evaluation of teachers and teacher evaluation of students, and quizzes. *Exclusion criteria*: Those who only participate in the partial teaching activities, and are absent or do not participate in any of the online questionnaire, mutual evaluation included student evaluation of teachers and teacher evaluation of students, and quizzes.

A exploratory-experimental study was performed assessing the efficacy of the innovative teaching approach for DM in laboratory medicine uses the clinical laboratory diagnostic pathway by the online questionnaire, mutual evaluation included student evaluation of teachers and teacher evaluation of students, and quizzes. The main purpose is to examine the problems and phenomena studied to achieve a preliminary understanding of this phenomenon. In addition, it can offer direction and hints for more in-depth, methodical, and exhaustive research.

The online questionnaire, mutual evaluation included student evaluation of teachers and teacher evaluation of students, and quizzes were executed anonymously without involving personal privacy information. This study was approved by the ethics committees of the Renmin Hospital of Wuhan University (WDRY2022-K093) and the exemption of informed consent in accordance with the Declaration of Helsinki.

Statistical analysis

The number of participants in various indicators of the DM clinical laboratory diagnostic pathway before and after teaching is recorded as $V_{1,\,2}\ldots$ and $V_{1',\,2'}\ldots$, respectively. Percent change $=(V_{1',}\,V_{2'}\ldots - V_{1,\,2}\ldots)/V_{1,\,2}\ldots \times 100\%$.[24] The test scores were presented as mean $\pm$ SD. The ratio paired *t*-test was used to compare the teaching quality evaluation and learning performance before and after teaching using the DM clinical laboratory diagnostic pathway. *P* values < 0.05 were considered significant differences. Statistical analyses were performed using Prism 8 (GraphPad Software Inc., USA).

Results

Routine testing items in the clinical laboratory for DM

Testing results in clinical laboratories are usually used to support the clinical doctor's decisions about the diagnosis, differential diagnosis, treatment, drug toxicity and side effects, efficiency monitoring, and prognosis evaluation. Routine testing items for the screening of DM are fasting plasma glucose (FPG), 2-hour plasma glucose (2hPG), HbA1c (A1c), total cholesterol, LDL-C, HDL-C, routine urine, liver function, kidney function, etc. Besides, diabetes-related genes are also needed when necessary, such as HNF1A, HNF4A, HNF1B, and GCK genes for the maturity-onset diabetes of the young (MODY), KCNJ11, ABCC8, GATA6, and PDX1 genes for neonatal diabetes mellitus (NDM). According to the selected guidelines for clinical diagnosis and treatment of DM, we divided diabetes diagnosis and treatment into multiple stages, including diagnosis and differential diagnosis, recognition of complications, selection of a treatment plan, evaluation of drug toxicity and side effects, monitoring of therapeutic effects, and prognosis evaluation. Many different testing items in the clinical laboratory were then integrated into the entire process of diabetes diagnosis and treatment (Figure 1). Serum biomarkers of DM such as FPG, A1c, random plasma glucose (RPG), and oral glucose tolerance test (OGTT) are detected for the diagnosis of diabetes, and amylase, lipase, and glucocorticoid are used for the diagnosis of secondary diabetes. Renal function and liver function detection are used for risk evaluation in pre-diabetic patients. Renal injury markers, atherosclerotic cardiovascular disease (ASCVD) risk assessment indicators, and liver injury indicators are used to formulate a protocol of treatment and health management and evaluate the prognosis of patients with confirmed diabetes. The side effects of drugs can be evaluated by monitoring liver function and renal function during treatment. Multiple indicators should be tested for the risk evaluation and disease staging of type 1 diabetes (T1DM). For example, positive autoantibodies

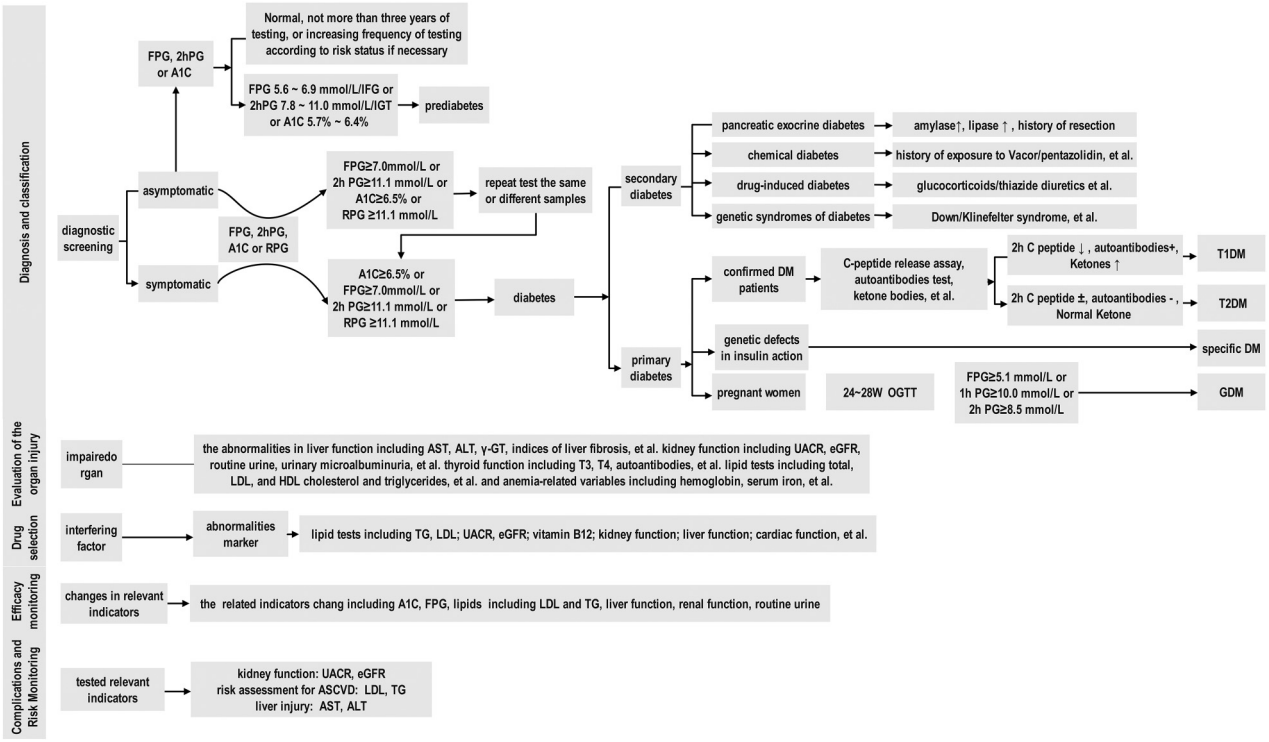

Figure 1. The schematic diagram of routine DM testing route in the clinical laboratory created by authors. There are five sections for routine DM testing including diagnosis and classification, evaluation of the organ injury, drug selection, efficacy monitoring, and complications and risk monitoring. FPG, fasting plasma glucose; 2hPG, 2-hour plasma glucose; A1C, HbA1c; UACR, urine albumin–creatinine ratio; eGFR, estimated glomerular filtration rate; IFG, impaired fasting glucose; IGT, impaired glucose tolerance; OGTT, oral glucose tolerance test; GDM, gestational diabetes mellitus; ASCVD, atherosclerotic cardiovascular disease.

can be found in stage 1 of T1DM, while abnormal impaired glucose tolerance (IGT) and impaired fasting glucose (IFG) can be found in stage 2. FPG, A1c, and 2hPG are used for the diagnosis of prediabetes. All indicators of diabetes in the clinical laboratory meet the criteria for a diagnosis of diabetes.

Clinical laboratory diagnostic pathway for DM

We discussed carefully with endocrinologists and other experts in the outpatient management department of our hospital and then established the clinical laboratory diagnostic pathway for diabetes. This kind of pathway also considered the characteristics of tertiary prevention of diabetes and the feasibility of clinical application (Figure 2). There is more information added to the DM clinical laboratory diagnosis pathway compared with the laboratory processing strategy in the DM routine laboratory testing process. Firstly, the screening for diabetes or prediabetes in the population of high-risk DM or occult DM was added to the screening strategy of the DM clinical laboratory diagnostic pathway, including the criteria for screening for diabetes or prediabetes in asymptomatic adults and the risk-based screening for T2DM or prediabetes in asymptomatic children and adolescents. Secondly, further processing strategies about the results near the margins of the diagnostic threshold and being diagnosed as T1DM have been added to the diagnostic screening in the DM clinical laboratory diagnostic pathway. The results should be repeated in 3 to 6 months according to the signs and symptoms of the patient if they are near the margins of the diagnostic threshold. The autoimmune conditions such as thyroid disease and celiac disease should be screened if the patient was diagnosed with T1DM. Thirdly, the test items about drug-related gene polymorphisms were added to the interfering factor of drug selection in the DM clinical laboratory diagnostic pathway, according to PharmGKB annotates.[25, 26] Fourthly, some tested relevant indicators were added to the complications and risk monitoring strategy in the DM clinical laboratory diagnostic pathway, such as indicators for the surveillance of gastrointestinal injury and small vessel inflammation, thyroid disease, and celiac disease. Finally, the content about remission of DM was added to the DM clinical laboratory diagnostic pathway to manage T2DM remission, including the assessment of the probability of T2DM remission and the evaluation of therapeutic effects for T2DM remission.

Evaluation of the teaching effectiveness of the clinical laboratory diagnostic pathway for DM

A questionnaire was conducted on the 17 relevant contents before and after the teaching of the DM clinical laboratory diagnostic pathway, including 9 laboratory medicine-relevant

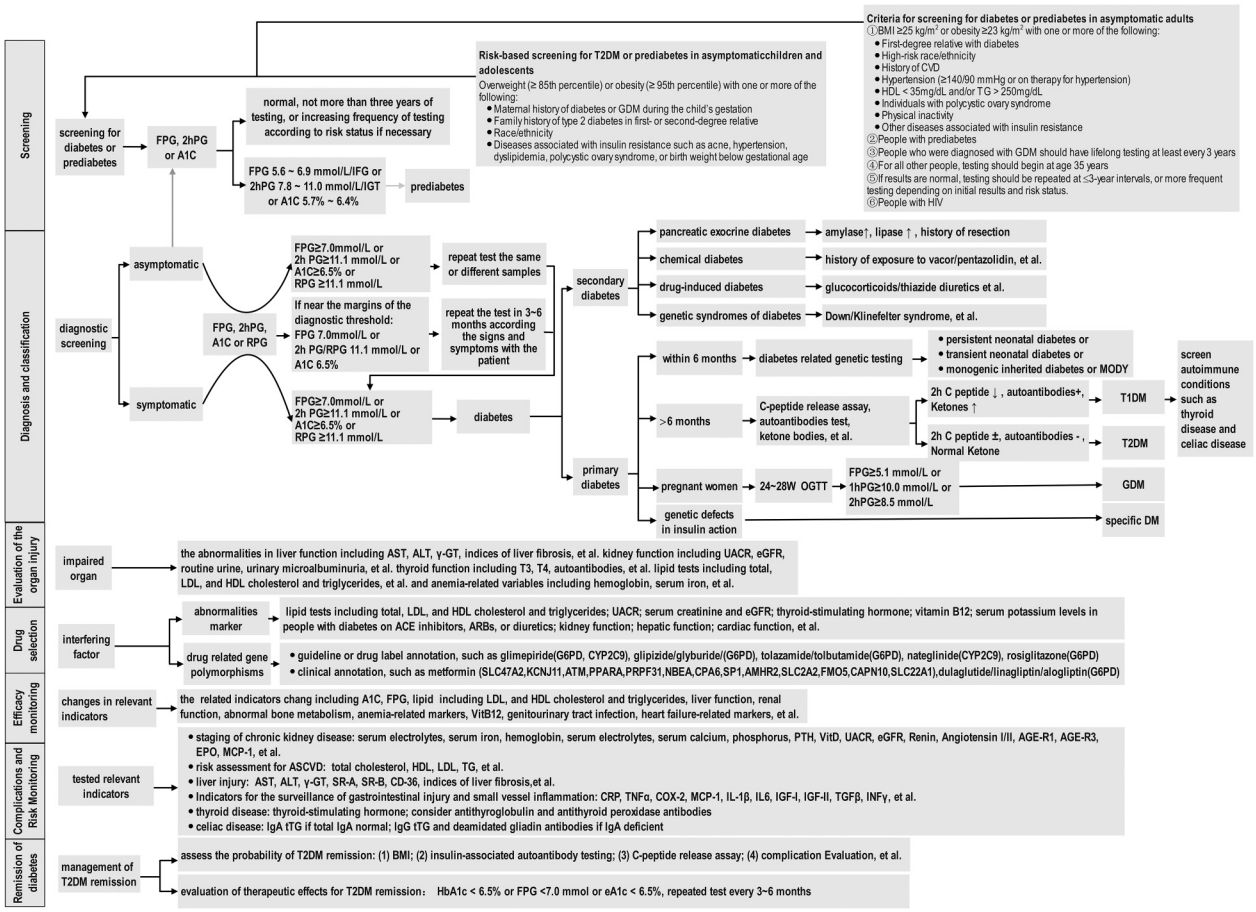

Figure 2. The schematic diagram of DM clinical laboratory diagnostic pathway created by authors. There are seven sections for DM clinical laboratory diagnostic pathway including screening, diagnosis and classification, Evaluation of the organ injury, drug selection, efficacy monitoring, complications and risk monitoring, and remission of diabetes. 1hPG, 1-hour plasma glucose; CVD, cardiovascular disease; PTH, parathyroid hormone; 25(OH)D, 25-hydroxyvitamin D.

contents and 8 clinical medicine-relevant contents (Table 1). About 35% of students surveyed (35.60 ± 7.90%) showed slight improvement, about 20% of students surveyed (17.16 ± 7.03%) showed more improvement, and 15% of students surveyed (13.62 ± 2.99%) showed significant improvement with conventional teaching methods for DM, but more than 30% of students surveyed (33.62 ± 8.96%) showed no improvement (Figure 3A). About 35% of students surveyed (35.89 ± 5.74%) showed significant improvement, about 30% of students surveyed (32.06 ± 4.72%) showed more improvement, and about 20% of students surveyed (18.44 ± 4.53%) showed slight improvement after DM clinical laboratory diagnostic pathway teaching (Figure 3B). At the same time, only about 10% of the students surveyed (13.62 ± 2.64%) showed no improvement after DM clinical laboratory diagnostic pathway teaching (Figure 3B). The training effectiveness significantly improved compared to before and after DM clinical laboratory diagnostic pathway teaching (before and after): no improvement (13.62 ± 2.64% and 33.62 ± 8.96%, $P < 0.0001$), slight improvement (18.44 ± 4.53% and 35.60 ± 7.90%, $P < 0.0001$), more improvement (32.06 ± 4.72% and 17.16 ± 7.03%, $P < 0.0001$), and significant improvement (35.89 ± 5.74% and 13.62 ± 2.99%, $P < 0.0001$). In clinical medicine, the significant improvement is the ability to manage and control diseases (40.43% and 10.64%) and the ability to guide outpatient patients (438.30% and 12.77%). In laboratory medicine, the significant improvement is the most obvious changes in communication skills in patient–doctor interactions (48.94% and 14.89%) and the expansion of the testing technology platform (46.81% and 12.77%). There is still a significant improvement in overall ability (more improvement + significant improvement, 61.07% and 30.16%).

The percent change is used to evaluate teaching effectiveness by comparing before and after teaching with the DM clinical laboratory diagnostic pathway. After teaching DM clinical laboratory diagnostic pathway, all evaluation results have improved. The proportion of improvement (124.20 ± 105.50%, ranging from 15.38% to 333.3%) and significant improvement (186.0 ± 80.29%, ranging from 85.71% to 375.0%) significantly increased. The proportion of no improvement (−58.24 ± 14.21%, ranging from −77.78% to −18.18) and slight improvement (−46.20 ± 116.33%, ranging from −68.18% to −14.29%) significantly decreased.

Table 1. Survey questionnaire for the processing ability of diabetes mellitus-related skills.

	ABILITY LEVEL										
CONTENTS	0	1	2	3	4	5	6	7	8	9	10
Expansion of testing technology platform	○	○	○	○	○	○	○	○	○	○	○
Recommendation ability for detection sequence	○	○	○	○	○	○	○	○	○	○	○
Ability to interpret inspection results	○	○	○	○	○	○	○	○	○	○	○
Recommendation ability for further testing	○	○	○	○	○	○	○	○	○	○	○
Comprehensive analysis ability for inspection results	○	○	○	○	○	○	○	○	○	○	○
Communication skills in patient–doctor interactions	○	○	○	○	○	○	○	○	○	○	○
Ability to record medical behavior	○	○	○	○	○	○	○	○	○	○	○
Ability to develop basic clinical skills	○	○	○	○	○	○	○	○	○	○	○
Understanding clinical laboratory diagnostic pathway	○	○	○	○	○	○	○	○	○	○	○
Ability to guide outpatient patients	○	○	○	○	○	○	○	○	○	○	○
Ability to guide hospitalized patients	○	○	○	○	○	○	○	○	○	○	○
Ability to manage and control diseases	○	○	○	○	○	○	○	○	○	○	○
Ability to manage other chronic diseases	○	○	○	○	○	○	○	○	○	○	○
Ability to diagnose and treat diseases	○	○	○	○	○	○	○	○	○	○	○
Ability to prevent diseases	○	○	○	○	○	○	○	○	○	○	○
Ability to comprehensively understand	○	○	○	○	○	○	○	○	○	○	○
Ability to learn overall medical knowledge	○	○	○	○	○	○	○	○	○	○	○

Notes: Each ability is divided into 10 levels ranging from 0 to 10, with 0 to 2 indicating no improvement, 3 to 5 indicating a light improvement, 6 to 8 indicating a more improvement, and 9 to 10 indicating significant improvement. Please choose the appropriate position based on your actual abilities.

Furthermore, the mutual evaluation was conducted between teachers and students, and we compared the teaching evaluation contents before and after teaching through the DM clinical laboratory diagnostic pathway. The student evaluations of teachers included the mental outlook of teachers, characteristics of teaching methods, knowledge structure in this discipline of teachers, the interactive status of students and teachers, and points highlighted. The results of students evaluated teachers significantly improved (characteristics of teaching methods: 79.63 ± 3.45 and 93.12 ± 4.95, $P < 0.001$; knowledge structure in this discipline of teachers: 87.27 ± 3.28 and 94.35 ± 4.78, $P < 0.001$; points highlighted: 73.71 ± 2.99 and 94.41 ± 4.02, $P < 0.001$; mental outlook of teachers: 87.94 ± 2.98 and 91.02 ± 3.12, $P = 0.005$) excepted for the interactive status of students and teachers (90.18 ± 3.99 and 92.87 ± 4.55, $P = 0.681$ (Figure 4). The teacher-evaluated students included accuracy in answering questions, motivation to participate, ability to answer questions, and ability to interact well with teachers. All of the results of the teacher-evaluated students significantly improved ($P < 0.001$). The contents of the self-evaluation included a good harvest during the teaching, stimulating learning interest and initiative, and a good foundation for subsequent learning or practice. All of the results of the student self-evaluation significantly improved ($P < 0.001$) (Figure 4).

Discussion

It is necessary to combine different sub-disciplines, such as basic clinical testing, biochemical testing, immunological testing, microbial testing, and molecular biological testing, and then establish a standard testing strategy in the process of disease diagnosis and therapy.[27] The technician and physician in the clinical laboratory should have the opportunity to fully participate in the clinical disease diagnosis and treatment because they can act as a bridge linking laboratory medicine and clinical medicine, enhance the value and role of laboratory medicine, and then reflect the importance and necessity of laboratory medicine in the process of diagnosis and treatment of diseases.[28]

The clinical laboratory diagnostic pathway for DM was based on the guidelines for diagnosing and treating DM. This kind of pathway was a new strategy for integrating the clinical testing items, covering the whole process of DM. We searched and found a variety of guidelines and consensus related to the diagnosis, therapy, and prevention of diabetes. Based on that, we raised a draft procedure to standardize the

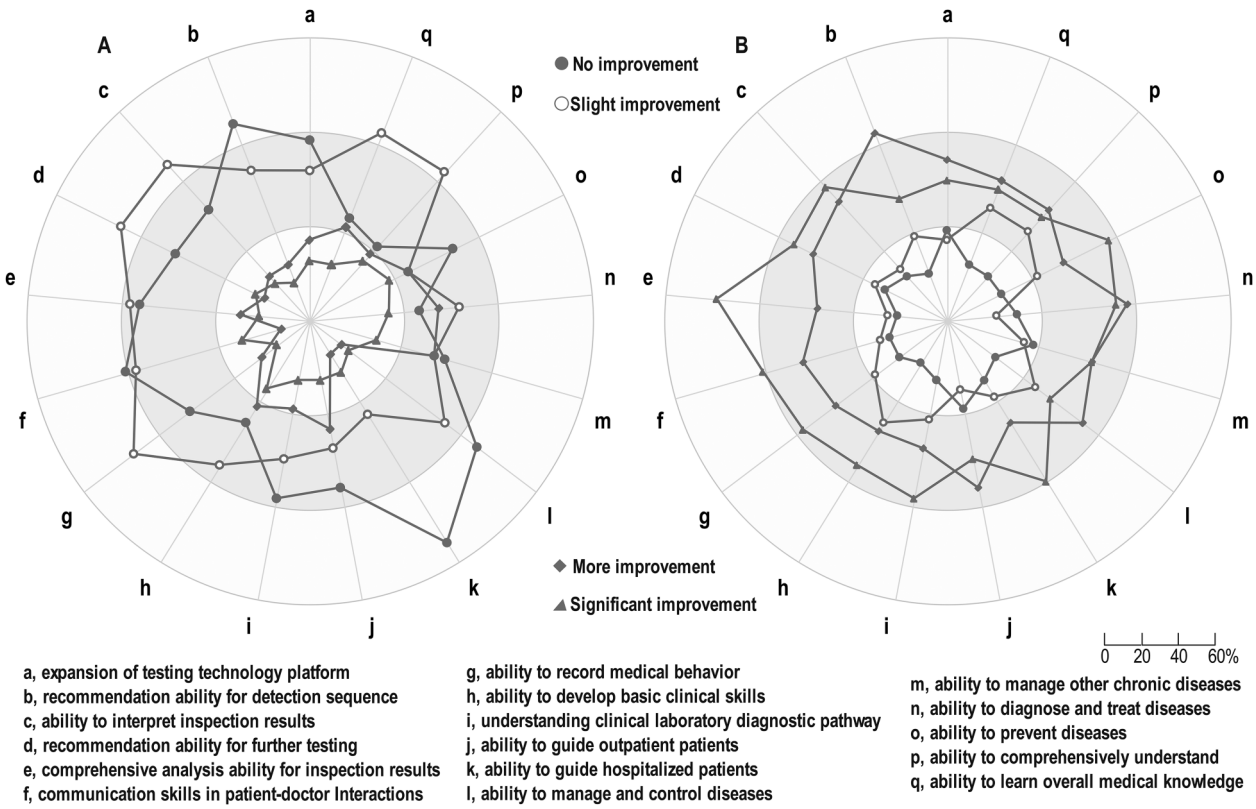

Figure 3. Self-assessment of improvement of learning by medical students. (A) Routine teaching mode (8-year medical undergraduates enrolled in 2018). (B) Clinical laboratory diagnostic pathway mode (8-year medical undergraduates enrolled in 2019).

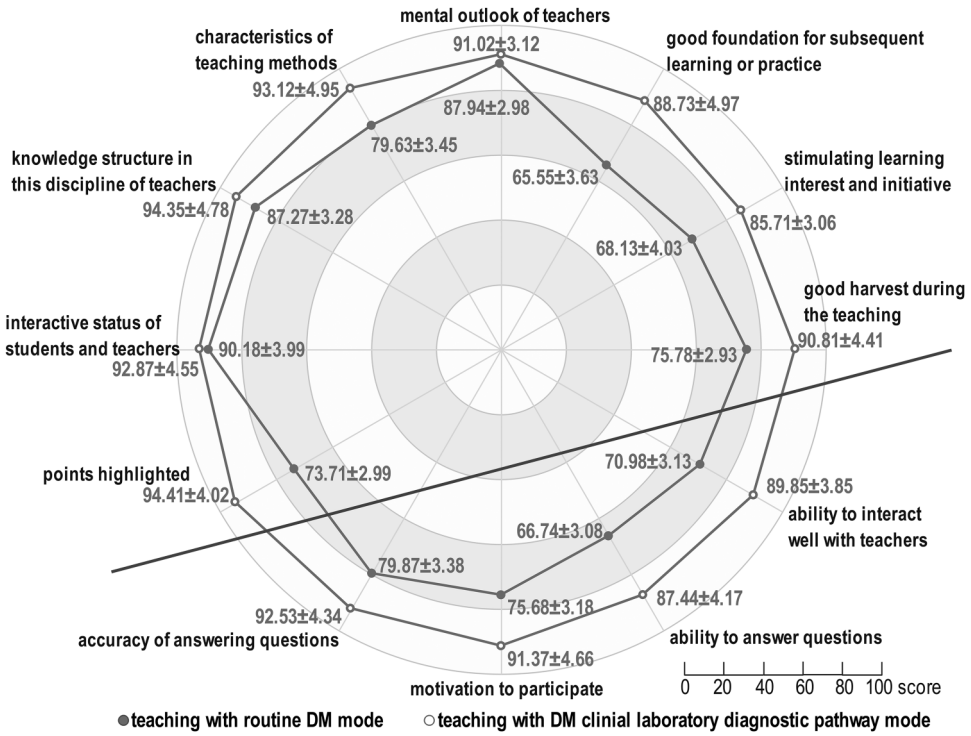

Figure 4. The results of teaching evaluation between teachers and students with DM clinical laboratory diagnostic pathway mode. The solid dot means teaching with routine DM mode in eight-year medical undergraduates enrolled in 2018, hollow dot means teaching with DM clinical laboratory diagnostic pathway mode in eight-year medical undergraduates enrolled in 2019. The student evaluations of teachers are above the slash, and the teachers evaluated students are below the slash.

testing items and schedule in the laboratory. After repeat and careful communication with endocrinologists and staff in outpatient offices, we further refined the draft pathway and separated the diagnosis and treatment process of diabetes into seven parts, including diagnosis, typing, evaluation of organ injury, decision of drug use, monitoring of therapeutic effects, observation of complications, and risk. Besides, we added the screening and alleviation of T1DM to the pathway, considering the primary and tertiary prevention of DM. As a result, the established novel clinical laboratory diagnostic pathway has become a comprehensive laboratory strategy ranging from prevention to diagnosis to treatment.

Laboratory medicine contains the main courses of diagnosis in clinical medicine, which is the bridge course connecting basic medicine with clinical medicine.[29] The routine teaching mode of laboratory medicine only focuses on testing items separately; thus, it is difficult for students to learn and remember, which will reduce their interest in learning, not to mention connecting clinical diseases.[30] Undoubtedly, the old teaching mode cannot meet the needs of teaching in laboratory medicine, so reform and innovation should be inevitable to change the routine teaching mode.

In our study, we established the new teaching mode based on the clinical laboratory diagnostic pathway of diabetes and then put it into the class of laboratory medicine for the medical undergraduates enrolled in 2019 compared with the routine teaching mode for the medical undergraduates enrolled in 2018. Firstly, we compared the teaching quality of the routine DM teaching mode with the DM clinical laboratory diagnostic pathway mode through a questionnaire. The results showed that almost all evaluation indicators have significantly improved ($P < 0.01$) (Figure 3). There was a significant improvement in "more improvement" and "significant improvement," and there were significant decreases in "no improvement" and "slight improvement" in clinical medicine ability, laboratory medicine ability, research ability, and teaching ability ($P < 0.01$) (Figure 3). These results showed that the teaching model based on the DM clinical laboratory diagnostic pathway is more easily accepted by the students, especially in terms of communication skills in patient–doctor interactions, ability to record medical behavior, ability to guide hospitalized patients, and ability to manage and control diseases (Figure 3). Secondly, teaching effectiveness was also assessed through the mutual evaluation between teachers and students. The results of students' evaluations of teachers showed the teaching mode of clinical laboratory diagnostic pathways has increased teachers' confidence and enriched their knowledge (the mental outlook of teachers, $P < 0.01$; knowledge structure in this discipline of teachers, $P < 0.01$) (Figure 4). At the same time, the results of teachers' evaluation of students showed that students' interest in learning has significantly increased (accuracy of answering questions, $P < 0.01$; ability to answer questions, $P < 0.01$) and they are more actively participating in classroom activities (motivation to participate, $P < 0.01$; ability to interact well with teachers, $P < 0.01$) (Figure 4). At the same time, students feel that their abilities have also significantly improved (good harvest during the teaching, $P < 0.01$; stimulating learning interest and initiative, $P < 0.01$; good foundation for subsequent learning or practice, $P < 0.01$) (Figure 4).

Limitations

However, there are several limitations to this study. Firstly, only two cohorts of undergraduate students undergraduate students enrolled in 2018 and 2019 were involved in the study, and the differences in their own knowledge backgrounds could lead to biased results. No analytics have been established regarding the formal performance of this model and its assessment. Secondly, we directly selected all students in the entire grade without screening for individual abilities. This may affect the results of the questionnaire, mutual evaluations, and quizzes because of their different responses. Thirdly, the DM clinical laboratory diagnostic pathway was established from the perspective of a clinical laboratory, ignoring the complexity of diabetes and the lack of an overall concept. Fourthly, this survey was jointly designed by the teaching teachers and has not been validated. There may be ambiguous expressions or deviations in the understanding of the options, leading to certain deviations in the survey conclusions. Further investigation should be performed on this model's effect on the entire DM process in real-time at the clinical laboratory.

Conclusion

Our work established a new teaching mode based on a clinical laboratory diagnostic pathway with the clinical significance of testing items and techniques according to different processes and parts of diseases. It is useful and acceptable for students to learn the characteristics of diseases and corresponding laboratory testing items. They can easily master the clinical significance of the items, not just remember them. Next, we are going to establish more clinical laboratory diagnostic pathways for different diseases and apply them to the teaching of laboratory medicine, thereby ensuring the sustainable development of the teaching quality of clinical medicine.

Authors contributions

TYQ, CHB, and WYY analyzed and interpreted the data from diabetes relative guidelines. TYQ, WZG, GJ, and WQ analyzed the teaching outcomes. TYQ, CHB WYY, and WJW lectured the pathway in the classroom. ZHY, BAY, and LHB were major contributors in writing the manuscript. All authors read and approved the final manuscript.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethical approval and consent to participate

This study was approved by the ethics committees of the Renmin Hospital of Wuhan University (WDRY2021-K093) and the exemption of informed consent following the Declaration of Helsinki. All methods were carried out according to relevant guidelines and regulations in the declaration.

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