Journal of Contemporary Educational Research, 2025, Volume 9, Issue 3
http://ojs.bbwpublisher.com/index.php/JCER
ISSN Online: 2208-8474
ISSN Print: 2208-8466

Construction of a New Clinical Teaching System for Non-Alcoholic Fatty Liver Disease (NAFLD) based on the Dynamic Training Model Integrating "Guidelines, Clinical Practice, and Scientific Research"

Suzhen Jiang, Nan Wu*

Peking University People's Hospital, Peking University Hepatology Institute, Infectious Disease and Hepatology Center of Peking University People's Hospital, Beijing Key Laboratory of Hepatitis C and Immunotherapy for Liver Diseases, Beijing International Cooperation Base for Science and Technology on NAFLD Diagnosis, Beijing 100044, China

Corresponding author: Nan Wu, wn_summer@163.com

Abstract: With the shift in the definition of disease from non-alcoholic fatty liver disease (NAFLD) to metabolism-associated fatty liver disease (MAFLD), as well as the rapid evolution of pathological classification and therapeutic targets, traditional clinical teaching models face challenges such as outdated guideline updates, disjointed translation of scientific research, and limited skill training. This study proposes a dynamic training model integrating "guidelines, clinical practice, and scientific research." Through stratified case-based teaching (e.g., FibroScan simulator and metabolic sand table), dynamic guideline analysis (comparing old and new evidence), and the integration of scientific thinking (visualization of CAND1 protein mechanism), a teaching system that integrates theory and practice is constructed. Innovatively developed smart assistant tools (AI decision support system, VR liver biopsy simulator) and a multi-dimensional evaluation system (deviation analysis of diagnosis and treatment pathways, milestone assessment) are used while emphasizing metabolic medicine integration (continuous glucose monitoring and digital therapy) and ethical privacy protection (federated learning framework). This model aims to cultivate students' evidence-based decision-making skills and scientific research transformation thinking through dynamic knowledge base construction and interdisciplinary collaboration, providing sustainable teaching solutions to cope with the rapid iteration of NAFLD diagnosis and treatment.

Keywords: Non-alcoholic fatty liver disease (NAFLD); Trinity teaching model; Metabolism-associated fatty liver disease (MAFLD); Clinical teaching reform; Smart assistant tools; Interdisciplinary integration; Evidence-based medicine

Online publication: March 27, 2025

1. Background of NAFLD knowledge iteration and teaching challenges

1.1. Rapid evolution of disease cognition

(1) Definition change: The terminology update from NAFLD to MAFLD (metabolism-associated fatty liver disease) reflects a profound shift in the understanding of the disease's underlying mechanism. The diagnostic criteria for MAFLD emphasize metabolic dysfunction (such as BMI ≥ 25 or the presence of diabetes, lipid abnormalities, etc.) and eliminate the absolute exclusion of alcohol intake, making the diagnosis more aligned with the pathological characteristics of metabolic syndrome [1,2]. This transition requires the teaching system to update the terminology framework on time and strengthen the teaching of the correlation between metabolic abnormalities and fatty liver disease.

(2) Detailed pathological classification: The 2023 EASL guidelines classify fatty liver disease into simple fatty liver (NAFL), non-alcoholic steatohepatitis (NASH), and fibrotic stages, and recommend FAST score (combining VCTE elasticity value, CAP, and AST) and NIS2+™ (based on blood biomarkers) as dynamic risk assessment tools [3]. For example, the FAST score has an AUROC of 0.74–0.95 in identifying fibrotic NASH, which is significantly better than traditional FIB-4 and APRI. It is necessary to combine case simulation in teaching to train its application.

(3) Breakthrough in treatment targets: The Yang Baofeng team discovered that the CAND1 protein inhibits the progression of NAFLD by regulating hepatocyte lipid deposition [4], while research on the *NgBR* gene at Hefei University of Technology revealed that statins inhibit the molecular pathway of adipogenesis by up-regulating *NgBR* [5]. Such mechanisms need to be visualized through 3D animation and gene editing models to strengthen the connection between basic research and clinical translation.

1.2. Shortcomings of traditional teaching methods

(1) Lagging guideline updates: There are significant differences between the 2017 AASLD guidelines and the 2023 EASL guidelines in terms of non-invasive diagnostic tools (such as upgrades recommended for MRE) and indications for liver biopsy. For example, the EASL guidelines emphasize VCTE as a first-line screening tool, while AASLD relies more on the FIB-4 score. It is necessary to cultivate students' dynamic evidence-based thinking through comparative analysis of old and new guidelines [6].

(2) Disconnect between scientific research and translation: Gut microbiota-liver axis studies have shown that an increase in *Bacteroidetes* abundance is associated with NASH in NAFLD patients, while a decrease in *Firmicutes* abundance is associated with fibrosis progression. However, such findings have not been fully integrated into clinical decision-making teaching [7]. Teaching should introduce cases of microbiota metabolomics, such as butyrate regulating adipogenesis through the LKB1–AMPK pathway [8].

(3) Limited skill training: The traditional teaching model that relies on liver biopsy is difficult to adapt to the popularization of non-invasive diagnostic techniques (such as FibroScan, NIS2+™) [9]. It is necessary to integrate VR liver biopsy simulators (with force feedback to evaluate puncture angle deviation) and AI-assisted elasticity value interpretation systems to improve operational safety and efficiency.

2. Design of the trinity teaching model

2.1. Clinical practice module

2.1.1. Stratified case-based teaching

(1) Screening phase: Utilize FibroScan simulator training to interpret liver stiffness measurement (LSM) and controlled attenuation parameter (CAP), combined with research data from Hepatology (showing a 43% missed diagnosis rate of fibrosis in patients with normal ALT levels), emphasizing the necessity of combining FIB-4 scores and imaging examinations. For example, LSM ≥ 9.5 kPa suggests significant fibrosis (F ≥ 3), requiring the initiation of secondary prevention measures.

(2) Treatment decision-making: Simulate the nonlinear effect of a 5% weight loss on liver fat content through a dynamic metabolic sandbox (e.g., for every 5 cm reduction in waist circumference, liver fat decreases by 8–12%). Compare the differences in the effects of GLP-1 receptor agonists (which improve insulin resistance) and FXR agonists (which regulate bile acid metabolism). Personalized plans were generated based on patients' HbA1c and BMI, such as prioritizing semaglutide and lifestyle interventions for patients with a BMI > 30 [1,2].

2.1.2. Integration of bedside skills

Conduct real-time teaching on spleen thickness measurement (normal value < 4 cm) using portable ultrasound equipment. Synchronously compare the diagnosis and treatment pathways of similar cases. For example, an increase in spleen thickness may indicate portal hypertension, requiring adjustments to anti-fibrotic strategies.

2.2. Dynamic guideline analysis module

(1) Comparison of old and new guidelines: Using the 2017 AASLD and 2023 EASL guidelines as templates, analyze the evolution of non-invasive diagnostic tools. For example, EASL lists VCTE as a first-line recommendation, while AASLD emphasizes the initial screening role of FIB-4. The priority of lifestyle interventions (weight loss of 3–5% to improve steatosis) and drug selection (pioglitazone limited to T2DM patients with biopsy-confirmed NASH) should be demonstrated through a "treatment pyramid" [1,2].

(2) Evidence level teaching: Analyze the differences in evidence strength between RCTs and observational studies. For example, compare the efficacy of vitamin E in non-diabetic NASH patients (based on the PIVENS trial) versus its potential risk of prostate cancer, to cultivate students' ability to balance risks and benefits.

2.3. Integration of scientific research thinking module

(1) Visualization of cutting-edge mechanisms: Use 3D animation to demonstrate how CAND1 deficiency exacerbates lipid deposition, correlating it with the clinical characteristics of metabolic decline in elderly patients. Showcase the pathway through which statins up-regulate NgBR to inhibit fat synthesis using genetically edited mouse models. (2) Translational medicine training: Guide students in designing a UK Biobank data analysis project to explore the correlation between sarcopenia (decreased grip strength) and liver fibrosis, or utilize metabolomics data to uncover associations between the bile acid profile and NASH progression.

3. Innovative teaching tools and evaluation systems

3.1. Development of smart assistant tools

(1) Dynamic metabolic sandbox: Generate virtual cases based on patient parameters (such as ALT, and waist circumference) to simulate the dynamic impact curve of weight loss interventions on liver fat (e.g.,

sustained improvement in steatosis with weekly weight loss of 0.5–1 kg). Integrate genomic data to predict drug responses (e.g., reduced sensitivity to statins in individuals with *PNPLA3* gene variations).

(2) AI decision support system: Construct a tree diagram of diagnosis and treatment pathways, providing real-time prompts for decision nodes that deviate from the guidelines (such as misuse of ω–3 fatty acids for NASH treatment). Utilize Natural Language Processing (NLP) to identify logical flaws in medical records (e.g., neglecting the evaluation of MetS components).

3.2. Multi-dimensional evaluation system

The multi-dimensional evaluation system covers three dimensions, as shown in **Table 1**.

Table 1. Multi-dimensional evaluation system

Dimension	Tool	Innovative points
Knowledge mastery	Guide dynamic question answering system	Automatic matching of the latest studies (e.g. CAND1 target)
Skill operation	VR liver penetrating emulator	Force feedback assessment of puncture angle bias (error < 5° is qualified)
Clinical thinking	Deviation analysis of diagnosis and treatment path	NLP identification of cases that neglect metabolic syndrome assessment

3.3. Milestone assessments

(1) Bronze stage: Complete the calculation of the FIB-4 index and risk stratification for 10 cases (low risk < 1.3, medium to high risk > 2.67). (2) Gold stage: Host a virtual MDT to discuss liver transplantation indications (MELD-Na ≥ 15 or presence of decompensation events), integrating expert opinions from cardiology (to evaluate cardiovascular risk) and nutrition (to develop postoperative dietary plans).

4. Interdisciplinary integration and ethical considerations

4.1. Integration of metabolic medicine

Simultaneously analyze continuous glucose monitoring data and changes in liver elasticity values, revealing that for every 1% increase in HbA1c, the risk of fibrosis increases by 1.5 times. Introduce digital therapy platforms (such as smart glass sensors to monitor drinking patterns), protect patient privacy through a federated learning framework, and generate personalized alcohol cessation intervention plans using AI.

4.2. Ethics and privacy protection

The virtual case library follows a federated learning framework, adopting ε-differential privacy techniques (such as noise injection) to prevent metabolic data leakage. Clarify the limitations of AI-assisted diagnosis (such as insufficient validation of NIS2+™ in ethnic minority populations) to avoid clinical misjudgment [10].

5. Sustainable development strategy

5.1. Dynamic knowledge base construction

Integrate top journal research quarterly (such as the mechanism of SH3RF2 targeting ACLY to improve NAFLD in "Hepatology," and clinical trials of resistant starch regulating liver fat through gut microbiota in "Cell

Metabolism"), updating the teaching case library [11,12].

5.2. Improvement of teacher qualifications

Create a "clinical-scientific research dual-qualified" certification program, utilizing HoloLens2 devices to carry out virtual teaching and research across hospital departments (such as real-time demonstrations of liver biopsy VR operations).

5.3. Patient-involved teaching

Recovered NAFLD patients were invited to share their experiences with lifestyle interventions (such as reducing liver fat by 30% with daily steps >8000), enhancing students' empathy in doctor-patient communication.

6. Conclusion

NAFLD teaching requires the construction of a dynamic system with "guidelines as the outline, clinical practice as the body, and scientific research as the wings." Through intelligent tools (such as the FAST score sandbox and federated learning case library), the lag in knowledge updating can be reduced, strengthening the cross-application of metabolic medicine and digital technology. The focus is on cultivating students' evidence-based decision-making abilities, awareness of scientific research transformation, and interdisciplinary collaboration thinking to meet the rapid iteration challenges of liver disease diagnosis and treatment.

Disclosure statement

The authors declare no conflict of interest.

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