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Network Pharmacology and Molecular Dynamics Simulation Study on the Mechanism of Wuda Jiangjun Ointment in Treating Chronic Lumbar Muscle Strain

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Abstract: *Objective:* To investigate the mechanism of Wuda Jiangjun Ointment in treating chronic lumbar muscle strain based on network pharmacology and molecular dynamics simulation. *Methods:* Active components of Wuda Jiangjun Ointment were identified using the TCMSP database, HERB database, and a review of relevant literature. SwissTarget Prediction, GeneCards, and OMIM databases were employed to predict targets related to chronic lumbar muscle strain. The intersection of drug and disease targets was obtained using the bioinformatics platform and imported into the STRING database to construct a protein-protein interaction (PPI) network. Cytoscape 3.10.2 software was used to visualize the PPI network and perform topological analysis to screen core targets. Functional enrichment analysis of GO and KEGG pathways for the intersecting targets was conducted using the DAVID database. A “drug-active component-disease-target” network diagram was constructed using Cytoscape 3.10.2. Molecular docking was performed using AutoDock software to simulate the binding of active components to target proteins. Furthermore, the Amber 24 software package was utilized to evaluate the binding stability between target proteins and active components. *Results:* A total of 75 active components and 350 corresponding potential targets of Wuda Jiangjun Ointment were screened, along with 2,159 disease targets for chronic lumbar muscle strain. There were 192 intersecting targets between the active components and the disease. Topological analysis of the PPI network identified TP53, AKT1, STAT3, etc., as core targets. Topological analysis of the “drug-active component-disease-target” network identified quercetin, dehydropipernonaline, tomentosin A, etc., as key components. GO and KEGG enrichment analyses indicated that the key pathways were primarily involved in the IL-17 signaling pathway, the AGE-RAGE signaling pathway in diabetic complications, and cellular senescence. Thus, the therapeutic mechanism was predicted to be related to inflammatory responses, among others. Molecular docking and molecular dynamics simulations verified that the core target proteins and active components exhibited good binding affinity. *Conclusion:* Wuda Jiangjun Ointment exerts anti-inflammatory effects and treats chronic lumbar muscle strain by participating in biological processes such as inflammatory responses through multiple components, targets, and pathways. This study provides a basis for further research into the molecular mechanisms.

Keywords: Wuda Jiangjun Ointment; Chronic lumbar muscle strain; Network pharmacology; Molecular dynamics simulation; Target prediction

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1. Introduction

Chronic lumbar muscle strain (CLMS) is a condition arising from prolonged overuse or chronic stress injury to soft tissues such as lumbar muscles, fascia, and ligaments, constituting one of the most common causes of chronic low back pain ^[1]. Clinically, it manifests as persistent dull pain or intermittent discomfort in one or both sides of the lumbar region, characterised by a protracted course prone to recurrent episodes ^[2]. Modern medical research identifies prolonged tension and fatigue within the lumbar musculature as primary risk factors for CLMS ^[3]. Pathologically, inflammatory mediators are involved throughout the process. Following acute or chronic injury to lumbar soft tissues, impaired local blood circulation disrupts the balance between tissue metabolic supply and demand. This leads to the accumulation of pathological metabolic by-products, triggering an aseptic inflammatory response that ultimately manifests as low back pain ^[4]. Traditional Chinese Medicine classifies this condition under categories such as “lumbar pain” and “muscle and tendon obstruction”^[5]. The core pathogenesis in CLMS patients lies in qi stagnation and impaired blood circulation, obstructing the meridians. This obstruction causes pain, manifesting as lumbar discomfort ^[6]. Currently, Western medical approaches to treating CLMS primarily include non-steroidal anti-inflammatory drugs (NSAIDs), neurotrophic agents, analgesics, and physical rehabilitation therapies. While these methods effectively alleviate pain and improve function in the short term, prolonged medication use may induce adverse reactions such as gastrointestinal discomfort and hepatic or renal impairment^[3]. Consequently, exploring safe, effective interventions with low recurrence rates has become a key focus in contemporary CLMS treatment research.

Traditional Chinese Medicine demonstrates notable efficacy in treating CLMS. Lifestyle factors, emotional stress, and environmental influences frequently disrupt the smooth flow of qi and blood in the lumbar region, rendering the qi stagnation and blood stasis pattern particularly prevalent in CLMS ^[7]. Wuda Jiangjun Ointment (WDJJO), an in-house formulation of Guangxi International Zhuang Medicine Hospital, comprises *Polygonum cuspidatum*, *Curcuma zedoaria*, *Boswellia serrata*, *Drynaria fortunei*, *Polygonum aviculare*, *Ligusticum chuanxiong*, *Panax notoginseng*, *Piper longum*, *Dracocephalum moldavica*, *Mirabilite*, Dragon’s Blood Resin, Borneol, and Fermented Black Bean with Ginger. This formulation synergistically promotes blood circulation, dispels stasis, relaxes tendons and activates meridians, regulates qi, and alleviates pain, thereby restoring smooth qi and blood flow, dissipating stagnation, and relieving discomfort ^[8]. Preliminary clinical observations indicate that Martial Arts General Ointment is widely employed in treating muscular pain, soft tissue injuries, osteoarthritis, rheumatoid arthritis, and neuralgia. It effectively promotes local blood circulation and improves stasis conditions, with its mechanism potentially involving inhibition of inflammatory responses and regulation of immune function. This study employs network pharmacology methods to predict the primary active constituents and potential mechanisms of action in Martial Arts General Ointment. Molecular docking and molecular dynamics simulations validate the binding affinity between these constituents and key targets, providing a theoretical foundation for further experimental research and clinical application.

2. Materials and methods

2.1. Screening of active ingredients and target prediction

Within the Traditional Chinese Medicine System Pharmacology Database and Analysis Platform (TCMSP) (<https://www.tcmsp-e.com/>), each herbal ingredient in Wudajunjiang Gao (*Polygonum cuspidatum*, *Curcuma zedoaria*, *Boswellia serrata*, *Drynaria fortunei*, *Polygonum aviculare*, *Ligusticum chuanxiong*, *Panax notoginseng*, and

Piper longum) as search keywords. Based on pharmacokinetic parameters and considering the topical application of this formulation, screening was conducted for active components with a drug-like property (DL) ≥ 0.18 to identify potential active constituents and their target sites. Concurrently, the HERB 2.0 database (<https://www.herb.ac.cn/>) and relevant literature were consulted to supplement the active components and target information for Chinese medicinal herbs not included in TCMSP (Feilongzhangxue, Mangxiao, Menthol, Longxuejie, Douchi Jiang). Finally, all candidate drug targets were input into the Uniprot database (<https://www.uniprot.org/>) for standardisation of their names into official gene symbols, facilitating subsequent network construction and functional analysis.

2.2. Disease target screening

Using “chronic lumbar muscle strain” as the search term, disease targets were obtained from the GeneCards (<https://www.genecards.org/>) and OMIM (<https://www.omim.org/>) databases. After merging and deduping disease targets from each database, their names were standardised via the Uniprot database to obtain CLMS targets.

2.3. Identification of drug-disease intersection targets

Acquisition of Drug-Disease Intersection Target Database WDJJO and CLMS targets were imported into Venny 2.1.0 (<https://bioinfo.gp.cnb.csic.es/>) to identify common drug-disease targets, with a Venn diagram generated.

2.4. Construction of protein-protein interaction (PPI) network and core target screening

The intersection targets of WDJJO and CLMS were imported into the STRING database (<https://cn.string-db.org/>). Homo sapiens was selected as the study species, with the confidence threshold set to highest confidence ≥ 0.9 . Unconnected nodes were hidden to generate the PPI network. Subsequently, the resulting PPI network was imported into Cytoscape 3.10.2 for visualisation analysis. The CytoNCA plugin was employed to calculate network topological parameters, including node degree, betweenness centrality, and closeness centrality. Core targets exhibiting key regulatory roles within the network were identified based on node degree values, with visualisation of the screening results.

2.5. Network construction and topological analysis

Construction and Analysis of the “Drug–Active Ingredient–Disease–Target” Network Diagram Using Cytoscape 3.10.2 software, we constructed an association network linking “Martial Arts General Ointment–Active Ingredient–Chronic Lumbar Muscle Strain–Target” to systematically reveal the potential key compounds responsible for the ointment’s therapeutic efficacy. Subsequently, the CytoNCA plugin was employed to perform topological feature analysis on the network, calculating parameters including node degree, betweenness centrality, and closeness centrality. Primary active ingredients were evaluated based on their node degree values.

2.6. GO functional and KEGG pathway enrichment analysis

The selected target intersection was subjected to GO functional annotation and KEGG pathway enrichment analysis using the DAVID database (<https://davidbioinformatics.nih.gov/>). Results for biological processes (BP), cellular components (CC), and molecular functions (MF) were extracted alongside KEGG pathway outcomes, with $P < 0.05$ serving as the significance threshold. In GO analysis, the top 10 BP, CC, and MF entries with the smallest P -values were selected for enrichment display. For KEGG pathway analysis, signalling pathways with P

< 0.05 and strong association with CLMS were prioritised for investigation. Finally, enrichment bar charts for GO functions and KEGG pathways were generated using the MicroBioinformatics platform.

2.7. Molecular docking validation

The top three key active components by network analysis score and the top three core targets were selected for molecular docking. First, the three-dimensional structures (ligands) of the selected active components were downloaded from the PubChem database (<https://pubchem.ncbi.nlm.nih.gov/>), while the corresponding three-dimensional crystal structures (receptors) of the core targets were obtained from the PDB database (<https://www.rcsb.org/>). Subsequently, the receptor proteins were pre-processed using PyMOL software to remove water molecules and redundant residues. AutoDockTools 1.5.7 was then employed to perform hydrogenation and charge optimisation on the ligands, converting both ligand and receptor files into pdbqt format. Following the configuration of Grid Box parameters based on the receptor active site, molecular docking calculations were conducted using AutoDock Vina^[9]. Finally, PyMOL was employed for visualisation and presentation of the docking results.

2.8. Molecular dynamics simulation

The Amber 24 software package was utilised to assess the binding stability between proteins and compounds. The LEaP tool was employed for system construction: loading the PDB structures of the native protein and its mutants, applying the ff14SB force field to describe the protein, and employing the GAFF force field for compound parameterisation. The system was placed in a TIP3P water tank with a boundary distance of 10.0 Å from the protein surface. Na⁺ and Cl⁻ ions were added to neutralise charges. To resolve structural conflicts, a two-stage energy minimisation was performed: first, constraints were applied to the protein backbone, optimising only the solvent and ions; subsequently, constraints were removed, and a full minimisation of the entire system was conducted. This combined the steepest descent method with the conjugate gradient method to ensure system stability. System equilibration occurred in two stages: initially, the system was heated from cryogenic temperatures to 300.0 K under isothermal conditions with the protein backbone constrained; subsequently, further equilibration under isobaric conditions adjusted density while maintaining 300.0 K and 1 bar pressure, progressively preparing the system for production runs. A 100 ns molecular dynamics simulation was run under isothermal and isobaric conditions at 300.0 K and 1 bar pressure, unconstrained, generating trajectories for subsequent analysis. The CPPTRAJ tool was employed to analyse the trajectories, calculating root mean square deviation (RMSD), radius of gyration (Rg), solvent-accessible surface area (SASA), root mean square fluctuation (RMSF), and hydrogen bond count. The MM/GBSA method was employed to estimate binding free energy. One hundred frames were extracted from the final 1 ns of the 100 ns trajectory to analyse van der Waals forces, electrostatic interactions, and polar and non-polar solvation contributions, expressed in kJ/mol.

3. Results

3.1. Active components and target screening results

Compounds from each medicinal ingredient of WDJJO were retrieved from the TCMSP database. Based on the requirement $DL \geq 0.18$, 75 chemical components were preliminarily screened: 10 from *Polygonum cuspidatum*, 18 from *Drynaria fortunei*, 15 from *Piper longum*, 8 from *Panax notoginseng*, 7 from *Ligusticum chuanxiong*, 8

from *Boswellia serrata*, 6 from *Schizonepeta tenuifolia*, *Curcuma zedoaria* 3 (see **Table 1**). This yielded 1,136 target genes for the identified active components, which were deduplicated to obtain 270 valid targets. As the TCMS database did not include the five medicinal ingredients Feilongzhangxue, Mangxiao, menthol, dragon's blood resin, and fermented black beans. These five herbs were identified via the HERB 2.0 database, literature searches, and retrieval of their canonical SMILES sequences from the PubChem database. Target predictions for these compounds were then generated using the Swiss Target Prediction online database. After deduplication of the predicted results, 80 targets were collected. Following consolidation, the total number of targets reached 350.

Table 1. Number of active components and targets of major Chinese medicinal herbs in Wuda Jiangjun Ointment

Chinese Medicinal Herb	Number of Active Components	Number of Targets
<i>Polygonum cuspidatum</i>	10	324
<i>Drynaria fortunei</i>	18	304
<i>Piper longum</i>	15	157
<i>Ligusticum chuanxiong</i>	7	42
<i>Cynanchum paniculatum</i>	6	16
<i>Curcuma phaeocaulis</i>	3	24
<i>Panax notoginseng</i>	8	253
<i>Boswellia carterii</i>	8	16

3.2. Acquisition of disease targets

A total of 2,000 and 200 CLMS targets were retrieved and screened from the GeneCards and OMIM databases respectively. Following data consolidation and deduplication, 2,159 relevant targets were obtained.

3.3. Acquisition of intersecting drug-disease targets

CLMS targets and WDJJO targets were input into the Venny 2.1.0 online diagramming platform, yielding 192 intersecting targets (see **Figure 1**).

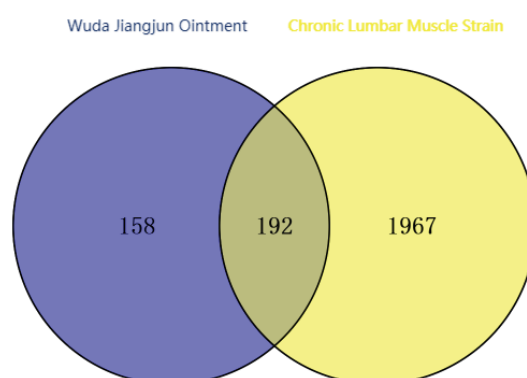


Figure 1. Venn diagram of target points for “Martial Arts General Ointment - Chronic Lumbar Muscle Strain”

3.4. Construction of PPI network and core target screening

The 192 intersecting targets were imported into the STRING protein interaction analysis platform, with species restricted to humans. Interactions with a protein interaction score ≥ 0.9 were selected, yielding the PPI relationship diagram (see **Figure 2A**). In **Figure 2A**, 191 nodes and 707 edges are visible, with each node representing a target protein. Protein-protein interactions are depicted as straight line connections; higher network connectivity density indicates closer relationships between proteins, providing a theoretical basis for further core target screening. The PPI network diagram was visualised using Cytoscape 3.10.2 software (see **Figure 2B**), where node size and colour intensity correspond to degree values—larger nodes and darker hues denote higher degrees. Concurrently, the top 10 core target nodes by degree were selected and plotted (**Figure 2C**), indicating these 10 targets as potential therapeutic candidates for WDJJO in chronic LMS treatment: TP53, AKT1, STAT3, JUN, ESR1, SRC, TNF, IL6, NFKB1, and HSP90AB1. Detailed parameters are presented in **Table 2**.

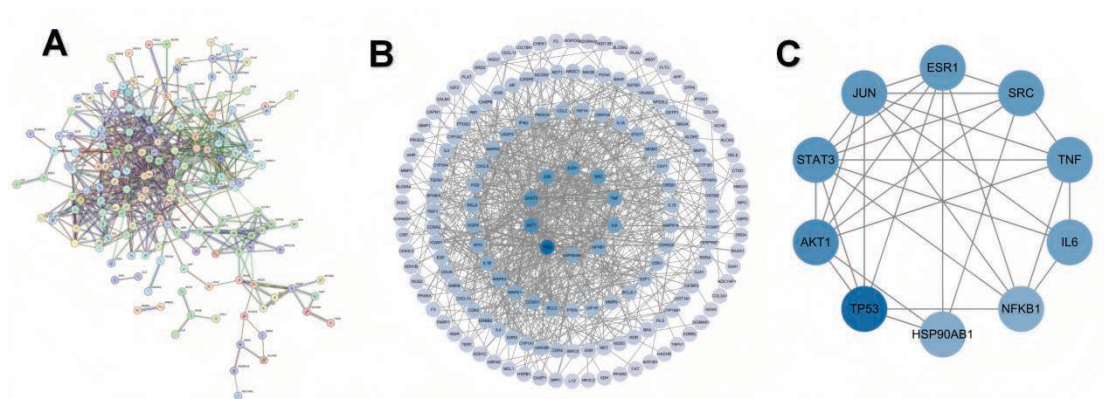


Figure 2. PPI network diagram of intersecting targets for “martial arts general ointment - chronic lumbar muscle strain”

Table 2. Topological analysis results of core target networks for “Martial Arts General Ointment - Chronic Lumbar Muscle Strain”

Target	Degree
TP53	54
AKT1	38
STAT3	34
JUN	32
ESR1	31
SRC	31
TNF	30
IL6	28
NFKB1	22
HSP90AB1	22

3.5. Construction and analysis of the “drug–active ingredient–disease–target” network diagram

The relationship network between “drug–active ingredient–disease–target” was visualised and analysed using

Cytoscape 3.10.2 software (see **Figure 3**). Red rectangles denote disease names, blue rectangles represent drug names, green rectangles indicate active ingredients, yellow rectangles denote pathway names, and purple rectangles signify shared targets. Node size in the network diagram is proportional to Degree values. The CytoNCA plugin within the software analysed the topological parameters of the active ingredient network. Results indicated that quercetin (MOL000098), dehydropipernonaline (MOL001561), and Tomentolide A (MOL005619) exhibit higher Degree values, indicating these components are the primary active constituents in WDJJO's treatment of CLMS.

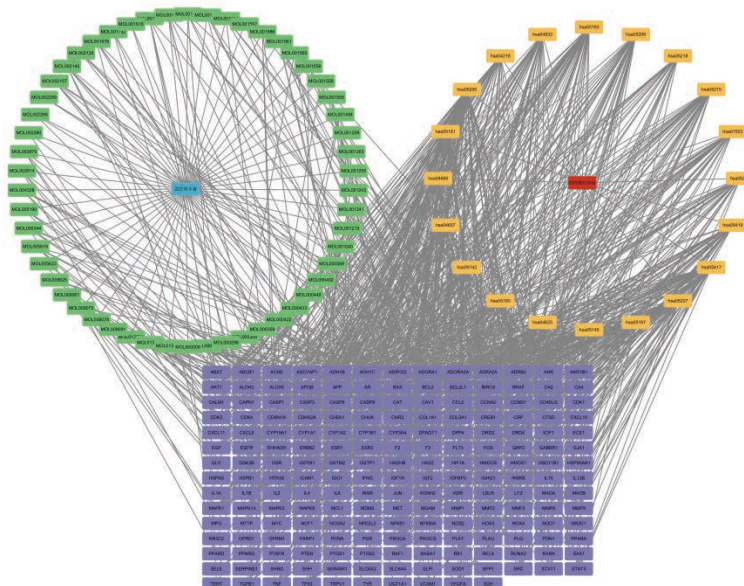


Figure 3. Network diagram illustrating the relationship between drugs, active ingredients, diseases, and targets

3.6. Gene ontology analysis and KEGG pathway enrichment analysis

The intersection targets of WDJJO treating CLMS were imported into the DAVID database for Gene Ontology (GO) analysis and KEGG pathway analysis, with data collected. Using $P < 0.05$ as the threshold, 736 entries for BP, 190 entries for MF, and 86 entries for CC were collected. The 10 entries with the smallest P -values from the BP, CC, and MF results were selected for enrichment analysis, and a GO enrichment bar chart was plotted (see **Figure 4**). Results indicate that WDJJO treatment of CLMS primarily enriches biological processes including positive regulation of gene expression, negative regulation of apoptosis, positive regulation of cell population growth, and positive regulation of microRNA transcription; tissue structures such as cytoplasm, plasma membrane, membrane raft, and receptor complex; and molecular functions including identical protein binding, enzyme binding, transcription coactivator binding, and nuclear receptor activity.

In the KEGG pathway enrichment analysis, 176 pathways were identified using a $P < 0.05$ threshold. The top 20 enriched pathways are presented in a KEGG pathway enrichment bubble plot (**Figure 5**). Results indicate that after excluding pathways unrelated to chronic lumbar muscle strain (e.g., cancer pathways, prostate cancer, toxoplasmosis), Wudajunjiang ointment treatment exhibited the most pronounced enrichment in inflammation-related metabolic pathways. Additionally, relevant pathways for WDJJO treatment of CLMS showed significant enrichment in IL-17 signalling pathways, AGE-RAGE signalling pathways in diabetic complications, and cellular senescence signalling pathways.

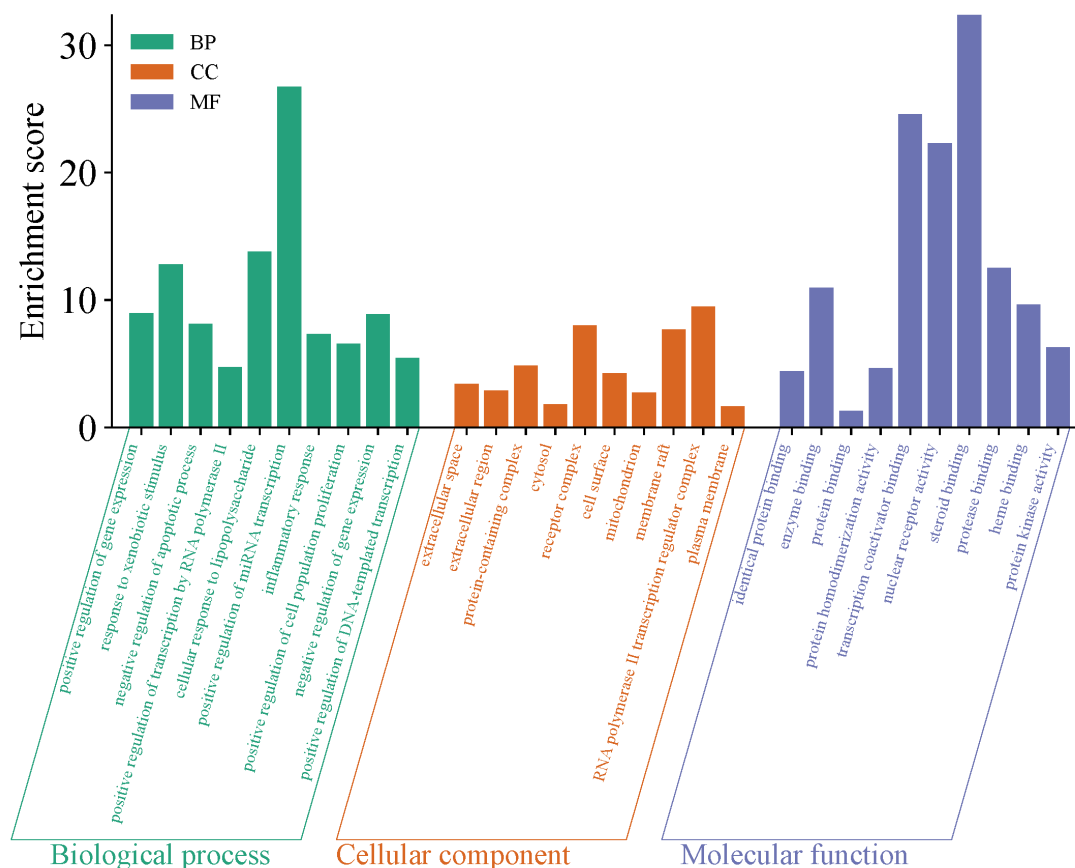


Figure 4. GO enrichment diagram for “Martial Arts General Ointment - Chronic Lumbar Muscle Strain”

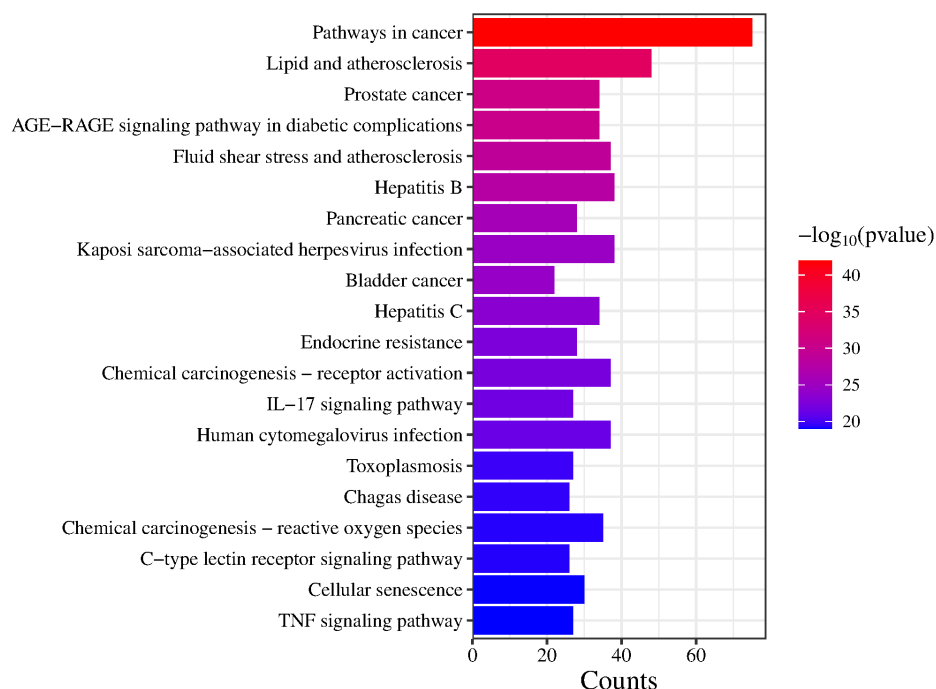


Figure 5. KEGG pathway enrichment diagram for “Martial Arts General Ointment - Chronic Lumbar Muscle Strain”

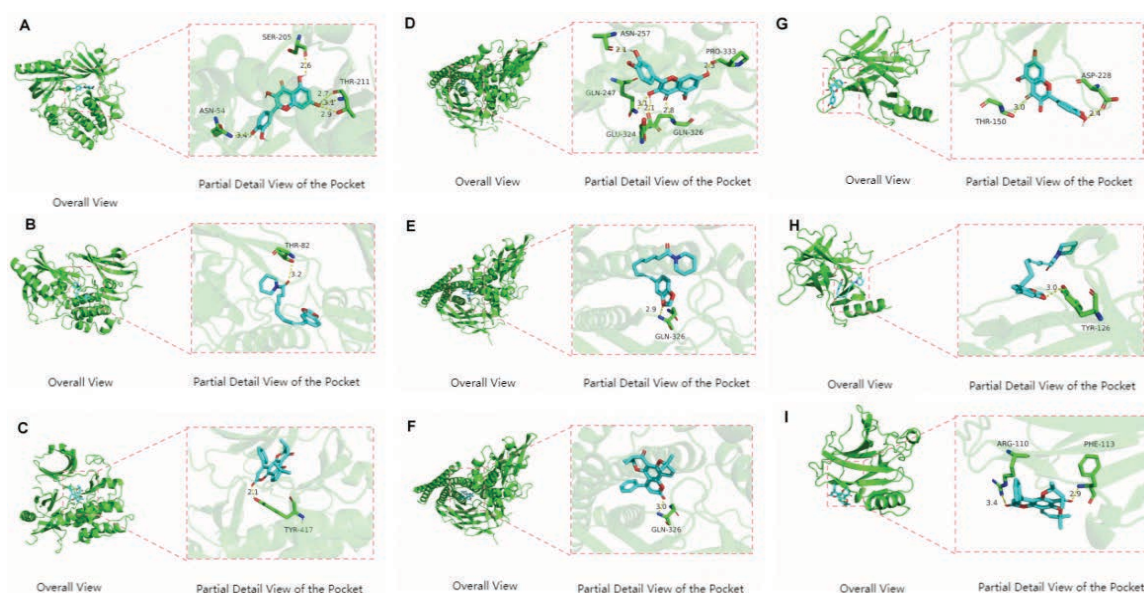
3.7. Molecular docking

To further validate the network pharmacology findings, the top three key active components with the highest degrees from the “drug-active ingredient-disease-target” network relationship diagram were selected as pharmacodynamic molecules. The top three core targets identified via PPI analysis—TP53, AKT1, and STAT3 as docking targets. Their binding energies were determined, yielding nine sets of docking results as shown in **Table 3**. Generally, docking energies below -4.25 kcal/mol indicate some binding activity, values below -5.0 kcal/mol denote favourable binding activity, while those below -6.0 kcal/mol signify strong binding activity

^[10]. The results demonstrate that the minimum binding energies for all compounds with the protein were below -4.25 kcal/mol, with 100% of compounds exhibiting binding energies \leq -5.0 kcal/mol. These findings indicate that the key active components of WDJJO predicted in this study exhibit favourable binding activity with critical therapeutic targets for CLMS, validating the scientific rigour and reliability of the network pharmacology predictions. Notably, the key component quercetin exhibited binding energies $<$ -6.0 kcal/mol with TP53, AKT1, and STAT3; dehydropipronalin with AKT1 and STAT3; and villus lactone A with TP53, AKT1, and STAT3, indicating favourable binding affinity. Molecular docking results were visualised using PyMOL software, as depicted in **Figure 6**.

Table 3. Docking results of proteins and ligands

Protein	Ligand	Binding Energy (kcal/mol)
AKT1	Quercetin	-9.8
AKT1	Dehydropipernonaline	-9.9
AKT1	Tomentolide A	-10.0
STAT3	Quercetin	-7.4
STAT3	Dehydropipernonaline	-6.9
STAT3	Tomentolide A	-8.1
TP53	Quercetin	-6.9
TP53	Dehydropipernonaline	-5.6
TP53	Tomentolide A	-7.7



Note: A: AKT1 and quercetin; B: AKT1 and dehydropipronalin; C: AKT1 and villus lactone A; D: STAT3 and quercetin; E: STAT3 and dehydropipronalin; F: STAT3 and villus lactone A; G: TP53 and quercetin; H: TP53 with dehydropipronalin; I: TP53 with vellan A

Figure 6. Visualisation of molecular docking results for core components of Wuda Jiangjun ointment and their binding energies with key target proteins

3.8. Molecular dynamics simulation

Molecular dynamics simulations were conducted using AKT1 and quercetin (MOL000098). The results are as follows:

3.8.1. Hydrogen bond analysis

To investigate the hydrogen bonding properties at the binding site of the AKT1-quercetin complex, we calculated the number of primary hydrogen bonds stabilising the interaction between AKT1 and quercetin. The results indicate that the number of hydrogen bonds between AKT1 and quercetin fluctuates minimally, remaining stable between 0 and 1 throughout the simulation. This suggests a relatively stable hydrophilic binding interaction between the two molecules (see **Figure 7A**).

3.8.2. RMSD analysis

Root mean square deviation (RMSD) serves as a crucial metric for assessing the stability of protein-ligand complexes. A flatter RMSD curve indicates greater complex stability. Results show that the RMSD curve for the AKT1-quercetin complex fluctuates within approximately 2 Å without significant variation, indicating high stability (see **Figure 7B**).

3.8.3. RMSF analysis

Root mean square fluctuation (RMSF) reflects the degree of motion exhibited by amino acid residues within a protein during simulation. Higher RMSF values indicate greater residue fluctuations, while lower RMSF values suggest reduced residue motion (see **Figure 7C**).

3.8.4. SASA analysis

Solvent-accessible surface area (SASA) measures the contact area between a protein surface and the solvent, serving as a crucial parameter for studying protein stability, interactions, and folding. Hydrophobic interactions constitute the primary driving force for protein folding, whereas regions in contact with the solvent are typically polar and exhibit weaker hydrophobic interactions. Results demonstrate a marked increase in SASA values around 10 ns and 60 ns, indicating enhanced interactions between the molecular surface and solvent. This may influence solubility, reactivity, and biological activity (see **Figure 7D**).

3.8.5. Rg analysis

The radius of gyration (Rg) is a physical quantity describing the compactness of a protein structure; a smaller Rg indicates a more compact and stable structure. The Rg curve calculated from molecular dynamics simulations shows that the Rg of the AKT1-quercetin complex remained stable throughout the simulation with minimal fluctuations, consistent with the stability of the RMSD curve. Minor fluctuations observed towards the simulation tail (around 60 ns) corroborated SASA analysis results, indicating overall good stability of the complex (see **Figure 7E**).

3.8.6. MM/GBSA analysis

The MM/GBSA (Molecular Mechanics/Generalised Born Surface Area) method is a widely employed computational approach for estimating the binding free energy of protein-compound complexes, thereby assessing

binding affinity and stability. In this study, 100 frames (one frame every 10 ps) were extracted from the final 1 ns of a 100 ns molecular dynamics trajectory for analysis. The binding free energy ($\Delta G_{\text{binding}}$) was estimated by comparing the free energy differences between the AKT1-quercetin complex, the receptor, and the ligand, as shown in **Table 4**.

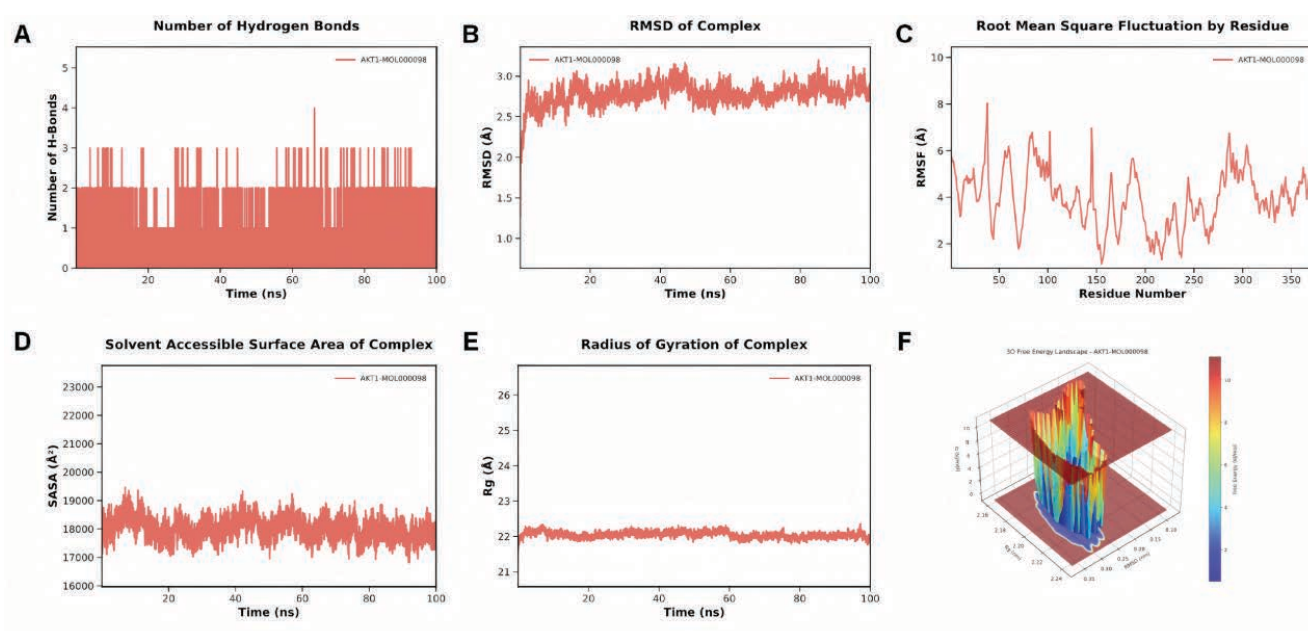
Table 4. Free energy distribution of AKT1-quercetin (MOL000098: quercetin) complex

Energy Type	Compound (kJ/mol)
E_VDW: Van der Waals Energy	-173.1348±8.4077
E_ELE: Electrostatic Energy	-51.0975±11.1943
E_GB: Polar Solvation Contribution	115.2930±10.6822
E_SA: Non-Polar Solvation Contribution	-21.6438±0.7301
$\Delta G_{\text{binding}}$: Binding Free Energy	-130.5835±9.2492

3.8.7. Free energy landscape analysis

By plotting the free energy distribution of the AKT1-quercetin complex in a two-dimensional space of root mean square deviation (RMSD) and radius of gyration (Rg) during molecular dynamics simulations, the conformational stability and dynamic behaviour of the complex were revealed. In the figure, RMSD indicates the deviation of the complex from its initial structure, Rg reflects the compactness of the molecular structure, and free energy (G, unit: kJ/mol) quantifies the thermodynamic stability of each conformational state. Low-free-energy regions (deep blue) correspond to stable conformations with high probability, typically representing energy troughs of the complex; high-free-energy regions (red) correspond to unstable transition states or low-probability conformations. Contour lines in the bottom-up projection further highlight densely populated regions of the free energy distribution, aiding identification of major conformational clusters and their distribution patterns. By analysing the free energy landscape, this study identified stable conformations of the complex within specific RMSD and Rg ranges, providing crucial thermodynamic insights into its binding mechanism and structural dynamics (see **Figure 7F**).

Molecular dynamics simulations and subsequent analysis demonstrated high stability for the AKT1-quercetin complex. RMSD and Rg analysis revealed minimal structural fluctuations and a compact complex architecture; RMSF indicated stable amino acid residue motion; SASA analysis revealed solvent interaction changes; hydrogen bond analysis confirmed the stability of hydrophilic interactions; MM/GBSA analysis further quantified the binding free energy, indicating that van der Waals forces and electrostatic interactions are the primary drivers of complex stability. These findings provide profound insights into the binding mechanism of the AKT1-quercetin complex, offering a theoretical basis for subsequent drug design and optimisation.



Note: A: Hydrogen bond count curve; B: RMSD curve; C: RMSF curve; D: SASA curve; E: Rg curve; F: Free energy landscape plot

Figure 7. Molecular dynamics simulation results for AKT1 and quercetin (MOL000098)

4. Discussion

Chronic lumbar muscle strain predominantly affects middle-aged and elderly individuals, manifesting primarily as recurrent aching pain in the lumbosacral region, with symptoms exacerbated by physical activity or climatic changes. The widespread prevalence of sedentary office work has led to prolonged static tension in muscle groups, resulting in an increasing incidence of this condition ^[11]. Its aetiology is closely associated with poor posture, repetitive lumbar loading, chronic cumulative injury, and incomplete recovery from acute trauma ^[12]. Persistent mechanical stress induces microdamage to soft tissues and local ischaemia, leading to metabolic dysfunction, retention of metabolic by-products, oedema, and aseptic inflammation, thereby triggering or perpetuating pain. The core mechanism involves chronic strain of lumbar soft tissues and disruption of the local microenvironment ^[13].

The Martial Arts General Ointment, an in-house preparation at Guangxi International Zhuang Medicine Hospital, has been utilised for many years. Within the formula, *Polygonum cuspidatum* possesses effects of promoting blood circulation to remove stasis, unblocking meridians to alleviate pain, and clearing heat to drain dampness; *Curcuma zedoaria* both regulates qi to relieve pain and breaks up blood stasis to disperse nodules; *Xu Changqing* is renowned for dispelling wind and alleviating pain. Together, these three herbs both invigorate blood circulation to remove stasis and regulate qi to relieve pain, addressing both symptoms and root causes, thus serving as the principal herbs. *Chuanxiong*, *Feilongzhangxue*, and *Bi Ba* complement the principal herbs by enhancing their effects in invigorating blood circulation to remove stasis, reducing swelling, and alleviating pain, collectively functioning as the auxiliary herbs. *Dipsacus asper* fortifies the kidneys, strengthens bones, and promotes blood circulation to heal injuries. *Boswellia*, *Panax notoginseng*, and *Dracaena draco* all invigorate blood circulation, unblock meridians, alleviate pain, and reduce swelling. *Piper longum* and fermented black beans, with

their pungent and warm nature, dispel cold, regulate qi, and expel wind, serving as auxiliary herbs to enhance the formula's efficacy in dispelling wind, unblocking meridians, and relieving pain. Menthol and Epsom salt serve as guiding agents: the former, aromatic and cooling, clears orifices and alleviates pain; the latter, cold and salty in nature, expels heat pathogens, reduces swelling, and disperses nodules. Together, they direct the formula into the meridians, harmonise the properties of the herbs, and enhance the overall therapeutic efficacy. The formula employs both cold and warm properties, combining tonification with dispersion. It invigorates blood circulation without harming the vital energy, removes stasis while alleviating pain, embodying the therapeutic principle that "unblocking relieves pain, and invigoration prevents stiffness".

Through the "medicine-active ingredient-disease-target" network analysis, the core components of Wu Da Jiang Jun Plaster for treating chronic lumbar muscle strain were identified as quercetin, dehydrated piperin nanol, and villus lactone A. Quercetin, a widely distributed flavonoid compound, exhibits multifaceted effects including anti-inflammatory, antioxidant, and anti-fibrotic properties^[14]. Its potential mechanisms may involve regulating the nuclear factor kappa-B (NF- κ B) signalling pathway, thereby inhibiting the release of pro-inflammatory cytokines (such as tumour necrosis factor- α (TNF- α) and interleukin-6 (IL-6)) and alleviating local aseptic inflammation^[15]. Furthermore, as a potent antioxidant, quercetin scavenges excess reactive oxygen species (ROS), mitigating oxidative stress-induced damage to muscle cells and surrounding tissues^[16]. Research indicates quercetin inhibits fibroblast differentiation into myofibroblasts and reduces synthesis of type I and III collagen, suggesting potential value in alleviating muscle tissue fibrosis during the late stages of chronic lumbar muscle strain^[17]. Dehydropiparone is an amide-type alkaloid whose mechanism of action is primarily hypothesised to involve analgesic and anti-inflammatory effects. Research into the mechanism of dehydrated piperine nonalin in treating chronic lumbar muscle strain remains limited. However, based on its structural characteristics and studies of similar compounds, it is hypothesised that it may exert analgesic effects on the central or peripheral nervous system by influencing ion channels such as the transient receptor potential vanilloid type 1 (TRPV1) or voltage-gated sodium channels, thereby alleviating chronic pain induced by lumbar muscle strain^[18]. Visceral lactone A is a structurally unique sesquiterpene compound exhibiting anti-inflammatory and cytoprotective effects^[19]. It may reduce inflammatory mediator production by inhibiting macrophage activation or blocking the mitogen-activated protein kinase (MAPK) signalling pathway, thereby mitigating inflammatory damage to muscle tissue^[20].

To determine the interrelationship of shared targets in Wu Da Jiangjun Ointment's treatment of chronic lumbar muscle strain, PPI topological analysis across diverse databases identified the top three key genes: TP53, AKT1, and STAT3. TP53, fully termed tumour protein 53, is fundamentally a transcription factor and one of the most crucial tumour suppressor genes within cells^[21]. It primarily regulates key biological processes including cell cycle arrest, DNA repair, cellular senescence, and apoptosis, playing a central role in maintaining genomic stability and intracellular homeostasis. The pathogenesis of chronic lumbar muscle strain involves chronic injury, inflammation, and abnormal remodelling of muscle and connective tissue cells. Research suggests that under conditions of muscle tissue injury or stress, TP53 activation may drive damaged cells towards apoptosis or senescence. While TP53-mediated apoptosis may aid in clearing severely damaged myocytes, excessive activation could lead to chronic muscle fibre loss and inadequate repair. Furthermore, the TP53-regulated cellular senescence process may induce the secretion of pro-inflammatory cytokines by surrounding tissues, thereby exacerbating chronic inflammation. This accelerates the pathological progression of lumbar muscle strain and impairs long-term functional recovery of the affected tissue^[22]. AKT1 is a pivotal member of the AKT serine/threonine protein kinase family and a key intracellular signalling molecule. It exerts central regulatory roles in cellular survival,

proliferation, metabolism, growth, and apoptosis^[23]. In chronic lumbar muscle strain, muscle tissue remains in a state of persistent stress and imbalanced repair. The AKT1 signalling pathway is recognised as a key pathway for muscle hypertrophy and growth, with its activity being crucial for muscle tissue regeneration and repair. Moderate AKT1 activity exerts a protective effect on the repair and regeneration of injured muscle, promoting myocyte survival, inhibiting apoptosis, and potentially regulating the balance between protein synthesis and degradation in muscle fibres. However, under certain chronic inflammatory or ischaemic stress conditions, abnormal or prolonged suppression of AKT1 signalling may lead to muscle atrophy and diminished repair capacity, exacerbating the pathophysiological process of chronic lumbar muscle strain. This manifests as reduced muscle strength and persistent, unresolved pain^[24]. STAT3, fully termed Signal Transduction and Activation of Transcription 3, is essentially a transcription factor mediating the signal transduction of various cytokines (such as IL-6, IL-10, etc.) and growth factors. It participates in regulating processes including inflammation, immune responses, cell proliferation, and differentiation^[25]. Inflammation constitutes a pivotal component in the pathogenesis of chronic lumbar muscle strain. As STAT3 serves as a key downstream signalling molecule for the pro-inflammatory cytokine IL-6, it plays a significant role in mediating chronic inflammatory responses within lumbar muscle tissue. Within the pathological environment of chronic lumbar muscle strain, sustained STAT3 activation may promote the expression of pro-inflammatory factors, establishing a vicious cycle of inflammation that continuously stimulates pain receptors. It may also influence fibroblast activity, potentially promoting fibrosis, leading to reduced muscle flexibility and scar formation, thereby further restricting movement and inducing chronic pain^[26].

GO analysis indicates that Wuda Jiangjun Ointment exerts specific effects in positively regulating gene expression, negatively regulating apoptosis, positively regulating cell proliferation, and influencing cytoplasmic, plasma membrane, enzyme-binding, and nuclear receptor activities. KEGG analysis indicates that Wuda Jiangjun Ointment may exert therapeutic effects on chronic lumbar muscle strain through inflammation-related metabolic pathways, IL-17 signalling pathways, AGE-RAGE signalling pathways in diabetic complications, cellular senescence, and other mechanisms. Relevant core targets also participate in multiple signalling pathways including PI3K/AKT and JAK/STAT. The IL-17 signalling pathway plays a pivotal role in the chronic inflammation of lumbar muscle strain. Upon binding to its receptor, IL-17 activates the ACT1-TRAF6 complex, subsequently initiating the NF- κ B and MAPK pathways to induce substantial expression of downstream inflammatory mediators (IL-6, TNF- α , IL-1 β)^[27]. Research indicates that IL-17 signalling can upregulate the TP53 stress response pathway, promoting cell cycle arrest and cellular senescence in injured tissues. Concurrently, by enhancing STAT3 phosphorylation, it sustains the chronic inflammatory microenvironment. Abnormal activation of this pathway may prolong inflammatory responses in muscle and fascial tissues while diminishing repair capacity, thereby propelling lumbar muscle strain towards chronicity^[28]. The PI3K/AKT pathway constitutes a crucial signalling axis regulating muscle cell survival, energy metabolism, and regeneration. Its core molecule, AKT1, plays a pivotal role in tissue repair during chronic lumbar muscle strain. PI3K activation promotes AKT1 phosphorylation; activated AKT1 inhibits myofibroblast apoptosis while promoting cell proliferation and maintaining metabolic homeostasis. Imbalance in this pathway may result in inadequate regeneration, metabolic disruption, and chronic pain^[29]. The JAK/STAT pathway holds significant importance in chronic inflammation and tissue repair mechanisms, with STAT3 serving as a pivotal transcription factor. In chronic lumbar muscle strain, cytokines such as IL-6 activate JAK kinases, leading to STAT3 phosphorylation and nuclear translocation. This regulates the expression of genes associated with inflammatory responses, apoptosis, and fibrosis. Persistently activated STAT3 promotes fibroblast proliferation and collagen deposition, leading to fascial adhesions and tissue stiffness. Concurrently, it interacts

with TP53 signaling to regulate the balance between cellular stress and apoptosis^[30]. This pathway plays a central role in sustaining chronic inflammation and tissue structural remodelling, constituting a key molecular target for chronic lumbar muscle strain.

Molecular docking results indicate that all compound pairs exhibit minimum binding energies below -5.0 kcal/mol, demonstrating high binding efficiency and strong affinity. Results show that quercetin, dehydropipronalin, and villus lactone A form stable docking models with TP53, AKT1, and STAT3, respectively. However, it should be noted that molecular docking outcomes may not always accurately reflect the most precise docking configuration. To address this limitation, MD simulations were conducted on the AKT1-quercetin complex system. Through various analyses, further evidence was obtained supporting the stability and strong binding between AKT1 and quercetin. Consequently, molecular docking and molecular dynamics simulation results indicate that Wuda Jiangjun Ointment exhibits stable binding with core targets, potentially exerting therapeutic effects on chronic lumbar muscle strain.

5. Conclusion

In summary, this study employed network pharmacology and molecular dynamics simulation to predict the potential mechanism by which Wuda Jiangjun Ointment treats chronic lumbar muscle strain through multi-component, multi-target, and multi-pathway interactions. This provides a theoretical foundation for its clinical application in treating chronic lumbar muscle strain and underpins subsequent pharmacological experimentation.

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Disclosure statement

The authors declare no conflict of interest.

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Impact of Standardized Anticoagulation Management Optimization on the Operational Quality and Clinical Outcomes of Continuous Renal Replacement Therapy

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Abstract: *Objective:* To evaluate the impact of optimizing a standardized anticoagulation management protocol on the operational quality of continuous renal replacement therapy (CRRT) and related clinical outcomes. *Methods:* This was a single-center retrospective quality improvement study. Adult patients who underwent CRRT for ≥ 24 hours in the Intensive Care Unit of Linfen People's Hospital between 2023 and 2025 were included. According to the implementation stages of the optimized anticoagulation management protocol, patients were divided into three annual groups. The distribution of anticoagulation strategies, filter lifespan per session, incidence of unplanned circuit interruption, bleeding complications, and ICU length of stay were compared among the three groups. *Results:* A total of 289 patients were included. With the implementation of the standardized anticoagulation management protocol, the proportion of regional citrate anticoagulation increased from 45.5% in 2023 to 83.5% in 2025. Filter lifespan was significantly prolonged (45.3 ± 12.1 h vs 72.4 ± 11.6 h, $P < 0.001$), while the incidence of unplanned circuit interruption and bleeding complications decreased over time (both $P < 0.05$). ICU length of stay also showed a downward trend ($P = 0.009$). *Conclusion:* The establishment and implementation of a CRRT-centered standardized anticoagulation management protocol were associated with prolonged filter lifespan, reduced complication rates, and improved operational quality of CRRT. This management approach may enhance the safety of blood purification therapy in critically ill patients in the ICU.

Keywords: Continuous renal replacement therapy; Anticoagulation management; Process optimization; Critical care medicine; Blood purification

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1. Introduction

Continuous renal replacement therapy (CRRT) is an essential organ support modality for critically ill patients

with acute kidney injury and multiple organ dysfunction^[1-2]. Compared with intermittent hemodialysis or other short-duration blood purification modalities, CRRT offers advantages such as hemodynamic stability and continuous removal of metabolic waste products and inflammatory mediators, making it widely used in the intensive care unit (ICU). However, the successful implementation of CRRT largely depends on appropriate and stable anticoagulation management. Inappropriate anticoagulation strategies or non-standardized management processes may lead to frequent filter clotting, unplanned circuit interruptions, and an increased risk of bleeding, thereby directly compromising treatment continuity and safety^[3].

In recent years, regional citrate anticoagulation has been increasingly adopted in CRRT, and anticoagulation management has gradually shifted from experience-based practice toward standardized and protocol-driven approaches^[4-5]. Against this background, we systematically reviewed and analyzed clinical data before and after the optimization of the anticoagulation management protocol in our institution. The aim of this study was to evaluate the impact of standardized anticoagulation management on CRRT operational quality and patient outcomes, and to provide practical evidence for CRRT management in regional ICUs.

2. Materials and methods

2.1. Study design

This study was designed as a single-center retrospective quality improvement study. Against the background of the gradual implementation and optimization of the CRRT anticoagulation management protocol at Linfen People's Hospital, a stage-based comparative analysis was conducted among patients who underwent CRRT during different periods to evaluate the impact of anticoagulation management optimization on CRRT operational quality and related clinical outcomes. The study period spanned from January 2023 to December 2025. According to the implementation progress of the optimized anticoagulation management protocol, patients were categorized into three annual groups (2023, 2024, and 2025), reflecting the evolving stages of protocol optimization and allowing assessment of trends in CRRT operational quality over time.

2.2. Study population

Clinical data were retrospectively collected from patients who underwent CRRT in the Intensive Care Unit of Linfen People's Hospital between January 2023 and December 2025. During the study period, other blood purification modalities, including hemoperfusion and plasma exchange, were also performed in our institution. However, given the substantial differences in indications and anticoagulation management strategies among treatment modalities, only patients receiving CRRT were included in the present analysis to ensure population homogeneity.

The inclusion criteria were as follows: (1) age ≥ 18 years; (2) receipt of CRRT for acute kidney injury or other critical illness-related indications; and (3) CRRT duration ≥ 24 hours per session. The exclusion criteria were: (1) incomplete clinical data; and (2) switching to another primary blood purification modality during treatment.

During the study period, the CRRT anticoagulation management protocol was gradually established and continuously optimized. To evaluate the impact of protocol optimization on treatment performance, patients were categorized into three annual groups (2023, 2024, and 2025) according to the stages of protocol implementation, reflecting the progressive improvement of anticoagulation management and its influence on CRRT operational quality and related clinical outcomes.

2.3. Optimization of the CRRT anticoagulation management protocol

During the initial stage of the study period (2023), anticoagulation strategies for CRRT were primarily selected based on clinicians' individual experience. Starting in 2024, our institution gradually developed and implemented a standardized CRRT anticoagulation management protocol, which entered a relatively mature phase in 2025. The main components of the protocol optimization included:

- (1) Establishing a unified CRRT anticoagulation management guideline, clearly defining indications and contraindications for anticoagulation;
- (2) Developing structured pathways for anticoagulation strategy selection under different clinical scenarios, with regional citrate anticoagulation (RCA) recommended as the first-line strategy;
- (3) Standardizing anticoagulant dose adjustment and monitoring procedures, including regular monitoring of activated partial thromboplastin time (APTT), electrolyte levels, acid–base status, and serum calcium concentrations;
- (4) Conducting targeted training programs for medical and nursing staff to improve consistency in the implementation of anticoagulation strategies;
- (5) Establishing a continuous evaluation and feedback system for CRRT operational quality and related complications, with regular analysis of filter lifespan and complication rates.

2.4. Outcome measures

The primary outcome measures included: (1) Distribution of anticoagulation strategies; (2) Filter lifespan per CRRT session (hours); (3) Incidence of unplanned circuit interruption; (4) Incidence of bleeding-related complications; (5) ICU length of stay (days).

Filter lifespan was defined as the duration from the initiation of a filter to its replacement due to clotting or other causes. Unplanned circuit interruption was defined as treatment discontinuation resulting from filter clotting or unexpected technical problems. Bleeding complications included gastrointestinal bleeding, bleeding at the catheter insertion site, or bleeding events requiring blood transfusion.

2.5. Statistical analysis

Statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were tested for normality and are presented as mean \pm standard deviation (SD). Comparisons among multiple groups were performed using one-way analysis of variance (ANOVA) for normally distributed data, and the Kruskal–Wallis test was applied for non-normally distributed variables. Categorical variables are presented as numbers (percentage) and were compared using the chi-square test or the chi-square test for trend, as appropriate. All statistical tests were two-sided, and a P value < 0.05 was considered statistically significant.

3. Results

3.1. Background of CRRT implementation

Over the past three years, the annual number of CRRT procedures and related extracorporeal organ support therapies in our institution has shown a steady increase (**Figure 1**), indicating a growing clinical demand for CRRT-based therapies among critically ill patients.

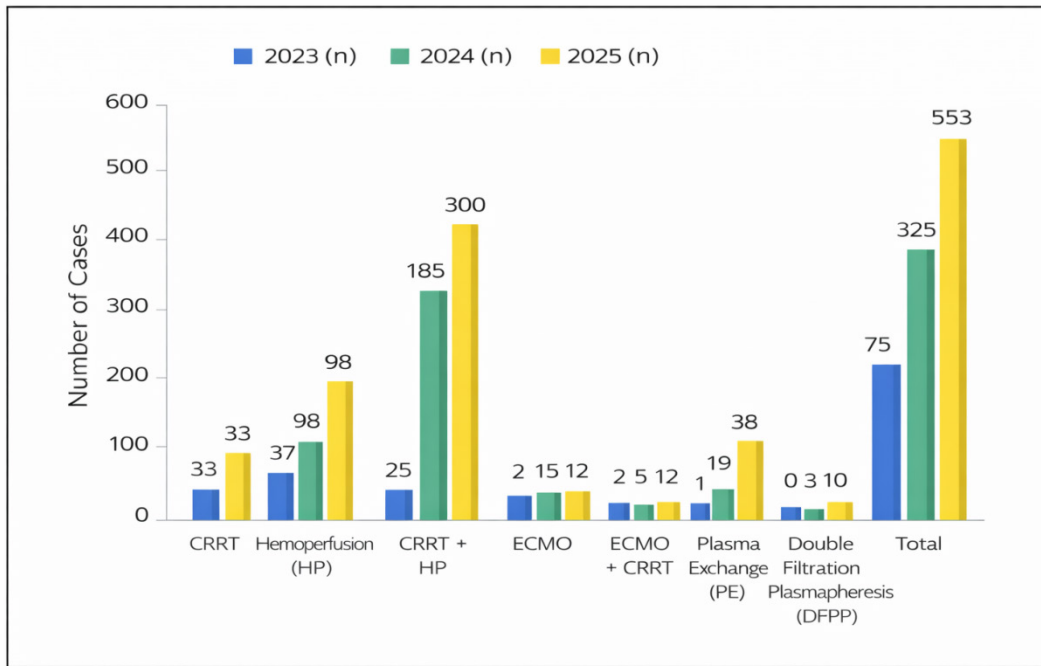


Figure 1. Annual trends in blood purification and extracorporeal support therapies from 2023 to 2025. Note: Annual trends in the utilization of blood purification and extracorporeal support therapies from 2023 to 2025. The number of cases increased steadily over the study period across most treatment modalities, particularly CRRT-based combined therapies

3.2. Baseline characteristics

No statistically significant differences were observed among the three groups in terms of sex, age, pre-treatment coagulation function, or distribution of primary diagnoses (all $P > 0.05$), indicating baseline comparability across groups (Table 1).

Table 1. Baseline characteristics and primary diagnoses of patients undergoing CRRT between 2023 and 2025

Variables	2023(<i>n</i> =33)	2024(<i>n</i> =98)	2025(<i>n</i> =158)	Statistic	<i>P</i> value
Baseline characteristics					
Male sex, <i>n</i> (%)	20 (60.6)	58 (59.2)	94 (59.5)	$\chi^2 = 0.032$	0.984
Age (years), mean \pm SD	65.2 \pm 8.5	64.7 \pm 9.1	63.9 \pm 8.3	$F = 0.432$	0.650
Baseline APTT (s), mean \pm SD	38.5 \pm 6.2	39.1 \pm 5.8	37.9 \pm 6.5	$F = 1.126$	0.326
Primary diagnoses, <i>n</i> (%)					
Septic shock	18 (54.5)	55 (56.1)	92 (58.2)	$\chi^2 = 0.841$	0.990
Acute kidney injury	12 (36.4)	35 (35.7)	54 (34.2)		
Others	3 (9.1)	8 (8.2)	12 (7.6)		

Note: Data are presented as mean \pm standard deviation (SD) or number (percentage), as appropriate. Comparisons among groups were performed using one-way analysis of variance (ANOVA) or χ^2 test. APTT, activated partial thromboplastin time; CRRT, continuous renal replacement therapy

3.3. Changes in anticoagulation strategy distribution

With the progressive optimization of the anticoagulation management protocol, the distribution of

anticoagulation strategies differed significantly across 2023 to 2025 ($\chi^2 = 25.89$, $P < 0.001$) (**Table 2**). The proportion of regional citrate anticoagulation increased steadily from 45.5% in 2023 to 83.5% in 2025, whereas the use of unfractionated heparin declined over the same period.

Table 2. Distribution of anticoagulation strategies during CRRT from 2023 to 2025

Anticoagulation Strategy	2023(<i>n</i> = 33)	2024(<i>n</i> = 98)	2025(<i>n</i> = 158)
Local citrate anticoagulation, <i>n</i> (%)	15 (45.5)	65 (66.3)	132 (83.5)
Unfractionated heparin anticoagulation, <i>n</i> (%)	12 (36.4)	25 (25.5)	20 (12.7)
Low-molecular-weight heparin anticoagulation, <i>n</i> (%)	4 (12.1)	6 (6.1)	5 (3.2)
No anticoagulation, <i>n</i> (%)	2 (6.1)	2 (2.0)	1 (0.6)

Note: Data are presented as a number (percentage). Differences in the distribution of anticoagulation strategies among the three groups were analyzed using the chi-square test ($\chi^2 = 25.89$, $P < 0.001$). CRRT, continuous renal replacement therapy; UFH, unfractionated heparin; LMWH, low-molecular-weight heparin

3.4. CRRT operational quality and clinical outcomes

Between 2023 and 2025, indicators related to CRRT operational quality demonstrated continuous improvement (**Table 3**). Filter lifespan was significantly prolonged ($F = 58.73$, $P < 0.001$). The incidence of unplanned circuit interruption and bleeding complications decreased over time, with statistically significant differences observed (both $P < 0.05$). ICU length of stay also showed a downward trend ($P = 0.009$). No significant difference was found in the rescue success rate among the three groups ($P = 0.127$).

Table 3. Comparison of CRRT operational quality and clinical outcomes from 2023 to 2025

Outcome Measures	2023(<i>n</i> = 33)	2024(<i>n</i> = 98)	2025(<i>n</i> = 158)	Statistic	<i>P</i> value
Filter lifespan (h), mean \pm SD	45.3 \pm 12.1	60.8 \pm 10.5	72.4 \pm 11.6	$F = 58.73$	<0.001
Unplanned circuit interruption, <i>n</i> (%)	3 (9.1)	5 (5.1)	2 (1.3)	$\chi^2 = 6.18$	0.045
Bleeding complications, <i>n</i> (%)	2 (6.1)	3 (3.1)	1 (0.6)	$\chi^2 = 6.07$	0.048
ICU length of stay (days), mean \pm SD	14.5 \pm 5.2	12.8 \pm 4.6	11.2 \pm 4.1	$F = 4.82$	0.009
Rescue success rate, <i>n</i> (%)	28 (84.8)	88 (89.8)	148 (93.7)	$\chi^2 = 4.12$	0.127
Vasopressor support required, <i>n</i> (%)	18 (54.5)	42 (42.9)	52 (32.9)	$\chi^2 = 8.65$	0.013

Note: Continuous variables are presented as mean \pm standard deviation (SD) and were compared using one-way analysis of variance (ANOVA). Categorical variables are presented as numbers (percentage) and were compared using the chi-square test. CRRT, continuous renal replacement therapy; ICU, intensive care unit

4. Discussion

The present study demonstrated that the implementation of a CRRT-centered standardized anticoagulation management protocol was associated with significant improvements in filter performance and reductions in complication rates. With the progressive optimization of the anticoagulation management process, the proportion of regional citrate anticoagulation (RCA) increased markedly, accompanied by a significant prolongation of filter lifespan. These findings suggest that optimization of the anticoagulation strategy structure may be an important factor contributing to improved CRRT operational quality. By achieving localized anticoagulation within the extracorporeal circuit and minimizing systemic anticoagulant exposure, RCA reduces the risk of systemic bleeding while helping maintain circuit patency, thereby prolonging filter

lifespan^[6]. The findings are generally consistent with previous studies reporting that RCA can extend filter lifespan and reduce bleeding risk, further supporting its broader application in CRRT practice^[7].

In addition, the standardization of anticoagulation management helps unify clinical decision-making pathways and reduce variability in anticoagulation strategy selection and dose adjustment among healthcare providers^[3, 8]. Through continuous training and the establishment of a quality feedback system, improvements in the timeliness and accuracy of anticoagulant dose adjustment and laboratory monitoring were achieved, which may have contributed to the observed reductions in unplanned circuit interruption and bleeding complications^[9]. Notably, the absolute number of unplanned interruptions and bleeding events was relatively small. Although statistically significant differences were observed, these findings should be interpreted cautiously and require validation in larger populations.

Furthermore, a decreasing trend in ICU length of stay was observed over the study period, suggesting that optimization of anticoagulation management may indirectly enhance overall treatment efficiency by improving the continuity and stability of CRRT^[10]. However, no significant difference was found in rescue success rates among the three groups, indicating that the impact of anticoagulation process optimization on short-term overall prognosis may be limited or influenced by multiple factors, including underlying disease severity^[11].

Based on real-world data from a single center, this study demonstrates a feasible approach to improving CRRT quality through management optimization in a regional ICU setting, with potential practical implications for routine clinical practice.

Several limitations should be acknowledged. This was a single-center retrospective study with a relatively small sample size, and residual confounding cannot be excluded. The stage-based comparison across years was not derived from a randomized design and may have been influenced by temporal trends or overall improvements in critical care practice. In addition, the small number of certain outcome events limits statistical robustness. Long-term outcomes were not evaluated, and adjustments for disease severity, such as SOFA score analysis, were not performed. Future multicenter prospective studies incorporating severity adjustment are warranted to validate these findings.

5. Conclusion

The establishment and implementation of a CRRT-centered standardized anticoagulation management protocol may improve CRRT operational quality, prolong filter lifespan, and reduce the incidence of certain complications. This management approach may provide practical value in optimizing blood purification therapy for critically ill patients in the ICU.

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Disclosure statement

The authors declare no conflict of interest.

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Application of Airway Clearance Combined with Postural Care in Patients with Severe Traumatic Brain Injury

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Abstract: *Objective:* To explore the systemic changes in respiratory function, the progression of pulmonary complications, and the potential for neurological recovery in patients with severe traumatic brain injury (sTBI) when applying an integrated approach that combines systematic airway clearance techniques with posture adjustment guided by cranial-cerebral physiological data. *Methods:* A total of 104 eligible sTBI patients were randomly assigned to a study group receiving integrated intervention (54 cases) and a control group receiving standard care (50 cases). Standard care followed general guidelines for neurocritical care, while the integrated intervention group underwent an additional comprehensive procedure: twice-daily airway clearance including positioning percussion, high-frequency vibration drainage, and image-guided pulmonary drainage, along with individualized progressive posture adjustments (such as phased elevation of the head of the bed and selective lateral positioning under image guidance) based on continuous monitoring of intracranial pressure (ICP) and cerebral perfusion pressure (CPP). Oxygenation index ($\text{PaO}_2/\text{FiO}_2$), respiratory mechanics parameters (plateau pressure, lung compliance), incidence of clinical pulmonary infection (CPIS criteria), duration of antimicrobial agent use, length of stay in the intensive care unit (ICU), and Glasgow Outcome Scale (GOS) at day 28 were evaluated and compared between the two groups before intervention, and on days 3 and 7. *Results:* By day 7 of intervention, the oxygenation index and lung compliance measurements in the study group were significantly higher than those in the control group ($P < 0.01$). The proportion of patients with clinical pneumonia and the constituent ratio of severe pneumonia ($\text{CPIS} \geq 8$) in the study group were significantly reduced ($P < 0.05$). The median duration of mechanical ventilation and the median length of ICU stay in the study group were shorter than those in the control group ($P < 0.01$). The 28-day outcome assessment showed that the proportion of patients with favorable recovery outcomes (GOS 4–5) in the study group was higher than that in the control group ($P < 0.05$). *Conclusion:* Implementing an integrated approach that combines structured airway maintenance with intracranial pressure-based posture control can effectively promote the recovery of pulmonary gas exchange efficiency in sTBI patients and reduce mechanical ventilation-related stress injury to lung tissue.

Keywords: Severe traumatic brain injury; Airway management; Posture adjustment; Intracranial dynamics; Pneumonia prevention

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1. Introduction

In the systemic pathological cascade triggered by severe traumatic brain injury (sTBI), respiratory dysfunction and secondary infections constitute critical secondary insults that significantly impact the clinical course of patients. Traditional nursing practices often treat airway secretion management and postural restrictions aimed at maintaining intracranial pressure (ICP) stability as separate issues, sometimes leading to conflicting management principles. This fragmented approach may fail to adequately address the complex interplay between brain and lung pathology under pathological conditions. A close interaction network exists among intracranial venous return dynamics, intrathoracic pressure changes, and alveolar recruitment status, suggesting the potential necessity for an integrative nursing support strategy that transcends traditional boundaries. This study aims to design and evaluate a collaborative nursing model that fundamentally seeks to bridge the operational gap between respiratory support and neuroprotection. By employing scientific scheduling and precise interventions, it aims to maximize the recovery of pulmonary physiological reserves while ensuring absolute stability of the intracranial environment, thereby exploring an integrated and practical clinical nursing pathway to optimize comprehensive treatment outcomes for sTBI patients.

2. Materials and methods

2.1. General information

The study subjects were sTBI patients admitted to the Neurosurgical Intensive Care Unit (NICU) of our hospital from June 2021 to December 2023. Inclusion criteria were clearly defined as follows: meeting the clinical diagnostic criteria for severe traumatic brain injury (Glasgow Coma Scale score between 3 and 8 upon admission); aged between 18 and 75 years; transferred to our hospital within one day of injury and expected to require more than three days of invasive ventilatory support; and obtaining informed consent from the patient's legal representative. Exclusion criteria included: pre-existing severe chronic obstructive pulmonary disease (COPD) or other underlying pulmonary conditions; cervical or thoracic spinal cord injuries, multiple rib fractures causing chest wall instability; clear evidence of pneumonia upon admission; expected survival of less than three days or concurrent life-threatening organ injuries. Ultimately, 104 patients were enrolled in the study and randomly assigned to the collaborative intervention group (54 cases) and the standard care group (50 cases) using a random number method. The study protocol was approved by the Institutional Ethics Review Committee (Approval No.: XYZ2021056).

2.2. Inclusion and exclusion criteria

The establishment of these criteria aimed to select a typical sTBI population in the acute phase, with relatively concentrated ages, and inevitably requiring prolonged ventilatory assistance due to their condition. By excluding patients with underlying diseases or injuries that could significantly affect respiratory function, as well as those with pre-existing infections upon admission, it maximizes the assurance that any differences in clinical outcome indicators between the two groups during subsequent observations can be more reasonably attributed to the different nursing interventions applied, rather than to heterogeneity in the initial status of the study population.

2.3. Intervention methods

The standard care group followed the general protocol for neurocritical care, which mainly involved open

suctioning based on airway secretion status, axial position changes every two hours, routine adjustment of ventilator parameters based on arterial blood gas analysis values, standardized enteral nutrition support, and administration of drugs to prevent stress ulcers. The collaborative intervention group, in addition to the above, implemented an integrated intervention protocol: In terms of airway clearance, twice-daily programmed procedures were performed by specially qualified respiratory therapists, integrating manual hyperventilation techniques, specific frequency (30–35 Hz) vibration-assisted drainage targeting the primary affected lung lobe (determined by auscultation or imaging), and closed-system suctioning after nebulized mucolytic agent administration. In terms of postural control, an hourly ICP and cerebral perfusion pressure (CPP) data monitoring-assessment-action cycle was established. Under the condition of real-time confirmation of safe ICP thresholds (<20 mmHg) and adequate CPP (>60 mmHg), a gradual postural adjustment strategy was implemented: for example, gradually elevating the head of the bed from 15 degrees to 30 degrees and maintaining it for a specific duration to optimize diaphragmatic function and lower lung zone ventilation; planning and ensuring a cumulative total of no less than four hours of side-lying positions with clear drainage orientation daily (choosing the affected or unaffected side based on imaging findings), and conducting intensive monitoring and recording of the patient's vital signs and intracranial hemodynamic indicators before and after each postural change.

2.4. Observation indicators

The primary observation indicators focused on respiratory system function, with arterial oxygen partial pressure, oxygenation index calculation, airway plateau pressure values displayed on the ventilator, and dynamic lung compliance calculation recorded at baseline (T0), the third day (T3), and the seventh day (T7) of intervention. Secondary observation indicators covered clinical endpoint events, including the incidence of ventilator-associated pneumonia meeting the Clinical Pulmonary Infection Score (CPIS ≥ 6 points) criteria, total days of antimicrobial therapy after pneumonia diagnosis, total duration of invasive mechanical ventilation, and total length of stay in the intensive care unit between the two groups. For neurological recovery assessment, the Glasgow Outcome Scale-Extended (GOS-E) was used to score all patients on the 28th day after the initiation of intervention measures, and the proportion of patients achieving a favorable recovery outcome (GOS rating of 4 or 5) within each group was statistically analyzed. All data collection and registration were independently completed by research assistants who were not involved in patient grouping and were unaware of the grouping situation to ensure objectivity.

3. Results

3.1. Comparison of baseline data between the two groups

Analysis and comparison of the demographic and clinical baseline characteristics of the two groups at the start of the study revealed no statistically significant differences (all P -values > 0.05) in mean age, gender ratio, classification of external causes leading to traumatic brain injury, immediate coma severity score upon admission, primary distribution of intracranial injury areas (cerebral hemisphere or cerebellar-brainstem region), and the presence of severe trauma in other systems between the two groups, as shown in **Table 1**.

Table 1. Comparison of baseline data between the two groups

Item	Collaborative Intervention Group(<i>n</i> = 54)	Standard Care Group(<i>n</i> = 50)	χ^2/t value	<i>P</i> value
Age (years, mean \pm SD)	44.8 \pm 13.2	46.9 \pm 12.5	0.825	0.411
Gender (male/female, <i>n</i>)	37 / 17	34 / 16	0.005	0.943
Cause of Injury (traffic accident/fall/other, <i>n</i>)	31 / 16 / 7	29 / 14 / 7	0.098	0.952
GCS Score on Admission (points, mean \pm SD)	5.3 \pm 1.5	5.4 \pm 1.7	0.321	0.749
Injury Location (supratentorial/infratentorial, <i>n</i>)	40 / 14	38 / 12	0.088	0.767
Presence of Polytrauma (yes/no, <i>n</i>)	18 / 36	16 / 34	0.042	0.838

3.2. Comparison of oxygenation and respiratory mechanics indicators between the two groups

At the initial baseline measurement time point (T0), the two study groups exhibited comparable levels in terms of the PaO₂/FiO₂ ratio reflecting oxygenation efficiency, plateau pressure reflecting ventilation pressure, and dynamic compliance reflecting lung tissue elasticity ($P > 0.05$). By the third day post-intervention (T3), the collaborative intervention group had demonstrated a numerical tendency towards superiority over the standard care group in oxygenation index and lung compliance, although the differences between the groups had not yet reached the threshold for statistical significance ($P > 0.05$). Upon measurement at the seventh day (T7), the PaO₂/FiO₂ values and dynamic lung compliance measurements in the collaborative intervention group had significantly surpassed those of the standard care group, while their mean airway plateau pressure readings were significantly lower than those of the standard care group. All these differences were highly statistically significant ($P < 0.01$), as shown in **Table 2**.

Table 2. Comparison of oxygenation and respiratory mechanics indicators between the two groups at different time points (Mean \pm SD)

Indicator	Group	T0	T3	T7	Inter-group Effect <i>P</i> value
PaO ₂ /FiO ₂ (mmHg)	Collaborative Intervention Group	181.5 \pm 44.8	238.2 \pm 37.5	287.2 \pm 31.5*#	< 0.01
	Standard Care Group	179.3 \pm 42.7	220.8 \pm 39.6	243.5 \pm 38.7*	
Platform Pressure (cmH ₂ O)	Collaborative Intervention Group	25.9 \pm 3.4	23.2 \pm 2.7	20.5 \pm 2.3*#	< 0.01
	Standard Care Group	26.3 \pm 3.0	24.8 \pm 3.2	23.9 \pm 2.9*	
Cdyn (mL/cmH ₂ O)	Collaborative Intervention Group	25.6 \pm 4.9	33.1 \pm 5.3	39.2 \pm 4.8*#	< 0.01
	Standard Care Group	25.0 \pm 5.0	30.5 \pm 5.8	33.0 \pm 5.7*	

Note: *indicates $P < 0.05$ compared with T0 within the same group; #indicates $P < 0.01$ for comparison between groups at the T7 time point

3.3. Comparison of pulmonary infection-related indicators between the two groups

Based on the clinical pulmonary infection scoring criteria, the overall incidence of ventilator-associated pneumonia in the collaborative intervention group was 15.0%, which was significantly lower than the 32.0% observed in the standard care group ($\chi^2=4.215$, $P=0.040$), as shown in **Table 3**.

Table 3. Comparison of pulmonary infection incidence between the two groups [n(%)]

Item	Collaborative intervention group(n=54)	Standard care group(n=50)	χ^2 value	P value
Total VAP Incidence Cases (CPIS ≥ 6)	8 (15.0%)	16 (32.0%)	4.215	0.040
Among which: CPIS 6-7	5 (9.3%)	7 (14.0%)	0.588	0.443
Among which: CPIS ≥ 8	3 (5.6%)	10 (20.0%)	5.012	0.025

3.4. Comparison of clinical and neurological prognosis indicators between the two groups

In terms of treatment process indicators, the median duration of invasive mechanical ventilation support for patients in the collaborative intervention group was 7 (5, 9) days, and the median length of stay in the intensive care unit (ICU) was 13 (10, 16) days. Both of these time indicators were significantly shorter than those in the standard care group. Specific data are summarized in **Table 4**.

Table 4. Comparison of clinical and neurological prognosis indicators between the two groups

Item	Collaborative Intervention Group(n=54)	Standard Care Group (n=50)	Statistical Value	P value
Duration of mechanical ventilation (days, M(P25, P75))	7 (5, 9)	11 (8, 15)	Z = -2.917	0.004
Length of ICU stay (days, M(P25, P75))	13 (10, 16)	17 (13, 21)	Z = -2.987	0.003
28-day GOS score ≥ 4 [n (%)]	23 (42.6%)	13 (26.0%)	$\chi^2 = 4.127$	0.042

4. Discussion

The data obtained in this study collectively confirm, from both physiological responses and final clinical outcomes, that for patients with severe traumatic brain injury (sTBI), a comprehensive nursing strategy that combines systematic airway clearance measures with posture adjustment based on intracranial pressure feedback yields statistically significant overall benefits superior to those of conventional nursing models. The effectiveness of this strategy is rooted in the synergistic and enhancing effects between different intervention components, rather than the mechanical accumulation of isolated technical approaches ^[1].

The positive impact of this integrated approach on the mechanical properties of the respiratory system and oxygen exchange capacity in patients is clearly supported by the data. The significant increase in dynamic lung compliance and the concurrent decrease in airway plateau pressure directly reflect a reduction in elastic resistance of the lung tissue and an improvement in ventilation efficiency. These positive changes may stem from the combined contributions of multiple mechanisms: targeted high-frequency vibration and pulmonary expansion techniques effectively clear viscous secretions obstructing the small and medium airways, reopening alveolar units that were closed due to mucus plugs; simultaneously, the progressive elevation of the head of the bed implemented under close monitoring optimizes the geometric shape and contractile efficiency of the diaphragm, increases functional residual capacity, and effectively counteracts the tendency for atelectasis in the lower lung regions caused by prolonged supine positioning. The sustained improvement in the oxygenation index serves as direct evidence of optimized matching between ventilation

and perfusion within the lungs, indicating that the intervention not only increases ventilation volume but may also indirectly benefit the perfusion efficiency of pulmonary capillaries by improving local circulation ^[2].

The effectiveness of this strategy in reducing the incidence of ventilator-associated pneumonia (VAP) highlights its significant clinical utility. The occurrence of VAP is essentially the result of an imbalance among microbial load, local and systemic host defense mechanisms, and iatrogenic intervention factors ^[3]. The integrated approach implemented in this study, through proactive, scheduled, and highly targeted airway clearance activities, substantially reduces the physical substrate—secretions retained in the airways—on which bacteria rely to proliferate and form biofilms. Meanwhile, the improved pulmonary ventilation and oxygenation status inherently enhance the phagocytic clearance function of local immune cells in the alveoli, creating a microenvironment unfavorable for pathogen proliferation ^[4].

The positive impact of this approach on indicators related to medical resource consumption and treatment efficiency holds considerable practical significance. The reduction in mechanical ventilation dependency time and the decrease in intensive care unit (ICU) length of stay are direct manifestations of the translation of the aforementioned physiological benefits into the realms of medical economics and operational efficiency ^[5]. The earlier liberation from the ventilator directly reduces the potential risks of ventilator-induced lung injury, complications related to the accumulation of sedative and analgesic drugs, and ICU-acquired muscle weakness in patients.

5. Conclusion

In summary, the organic integration of posture regulation following intracranial pressure principles with systematic airway clearance techniques constructs a novel “brain-lung integration” management paradigm adapted to the special pathophysiological state of patients with sTBI. This paradigm not only achieves clear effects in improving respiratory function, controlling infection occurrence, and optimizing medical resource utilization.

Disclosure statement

The authors declare no conflict of interest.

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Application of Quality Control Circle Activities in Improving the Standardization Rate of Robot-Assisted Pancreaticoduodenectomy Cooperation Among Rotating Nurses in the Operating Room

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Abstract: This study aimed to explore the effect of Quality Control Circle (QCC) activities on improving the standardization rate of robot-assisted pancreaticoduodenectomy cooperation among rotating nurses in the operating room. A total of 26 surgeries were divided into the control group (13 cases, routine mode) and the observation group (13 cases, QCC mode) based on time. With the PDCA cycle, targeted quality improvement was conducted. Results showed that the cooperation standardization rate in the observation group increased from 77.88% to 97.76%, preoperative instrument preparation time shortened from (15.3±2.1) min to (8.5±1.2) min, and error incidence dropped from 15.38% to 1.54% ($P<0.05$). Medical-nursing satisfaction also improved significantly. QCC can effectively standardize cooperation, optimize surgery flow, and enhance satisfaction, providing a feasible scheme for nursing quality control in complex robotic surgeries.

Keywords: Robotic surgery; Quality control circle; Standardization rate of surgical cooperation

Online publication: May 31, 2026

1. Introduction

1.1. Research background

Pancreatic cancer is a malignant tumor of the digestive system with an extremely poor clinical prognosis, ranking 13th in the incidence of malignant tumors worldwide and rising to 7th in mortality, with an overall 5-year survival rate of less than 10%, known as the “king of cancers”^[1-2]. Pancreaticoduodenectomy, as a radical surgical procedure for the treatment of pancreatic head cancer, periampullary cancer, duodenal malignant tumors, and other diseases, involves the resection of multiple organs such as the pancreatic head, duodenum, gallbladder, and part of the stomach, as well as the triple digestive tract reconstruction

of pancreaticojejunostomy, choledochojejunostomy, and gastrojejunostomy. It has complex anatomical structures, large surgical wounds, high requirements for operational accuracy, and great difficulty in preventing and controlling perioperative complications, which have always been one of the most difficult surgical procedures in general surgery^[3-4]. With the iterative upgrading of the concepts of minimally invasive surgery and precision surgery, the da Vinci robotic surgical system has gradually become the mainstream surgical method for pancreaticoduodenectomy by virtue of its core advantages, such as three-dimensional high-definition stereoscopic vision, 7-degree-of-freedom robotic arms, fine tremor filtering, and remote control. It can effectively reduce surgical trauma, reduce intraoperative blood loss, shorten the postoperative recovery cycle, and further improve the feasibility of complex surgeries^[5-6].

At the same time, robot-assisted pancreaticoduodenectomy puts stringent requirements on the professionalism, coordination, and emergency response capabilities of the operating room nursing team. As the core force of talent reserve in operating room subspecialties, rotating nurses generally have problems such as short working years, unfamiliarity with robotic equipment operation, poor understanding of complex surgical processes, insufficient professional knowledge reserves, and lack of understanding of the chief surgeon's operating habits. These problems easily lead to omissions in preoperative supplies preparation, delayed intraoperative instrument replacement, non-standard aseptic operation of robotic arms, and lagging emergency cooperation. These situations not only prolong the surgical duration, increase instrument loss and medical costs, but also may raise potential safety hazards such as intraoperative infection and operational errors, directly affecting the surgical progress and patient prognosis^[7-9]. As a quality management tool for full participation, autonomous management, and continuous improvement, the Quality Control Circle is a group composed of personnel in similar work scenarios. It uses quality control methods such as Pareto chart, fishbone diagram, and brainstorming to solve practical clinical problems, and has achieved remarkable results in the optimization of operating room nursing processes, professional training, and risk prevention and control^[10-11]. Based on this, this study carried out a special quality improvement activity of QCC targeting the non-standard cooperation of rotating nurses in the operating room in robot-assisted pancreaticoduodenectomy, and constructed a standardized cooperation system to provide a practical basis for improving the nursing quality of complex robotic surgeries.

1.2. Research objectives

Focusing on the pain points of rotating nurses in the cooperation of robot-assisted pancreaticoduodenectomy, this study set four research objectives: (1) to comprehensively investigate and accurately analyze the core problems and root causes of non-standard surgical cooperation of rotating nurses; (2) to formulate targeted, implementable and quantifiable quality improvement countermeasures and implement them in an orderly manner; (3) to objectively evaluate the improvement effect of QCC activities on the standardization rate of surgical cooperation, surgical efficiency, incidence of errors and the satisfaction of medical staff; (4) to establish a standardized, replicable and promotable special training and surgical cooperation management system for rotating nurses, and lay a solid foundation for the cultivation of nursing talents in operating room subspecialties.

1.3. Definition of core concepts

1.3.1. Robot-assisted pancreaticoduodenectomy

A minimally invasive and precision surgical procedure that uses the da Vinci Xi/Xi HD surgical system,

with surgeons controlling robotic arms to complete the resection of target organs such as the pancreatic head, duodenum, and gallbladder, as well as digestive tract reconstruction, which requires the coordinated cooperation of scrub nurses, circulating nurses, and equipment nurses throughout the process^[12].

1.3.2. Standardization rate of surgical cooperation

The percentage of the number of standardized operations of rotating nurses in the whole process of preoperative preparation, intraoperative coordination, and postoperative finishing, which conform to the aseptic operation specifications, equipment operation standards, surgical process requirements, and emergency disposal plans, accounting for the total number of inspected operations. It is a core quantitative index to evaluate the quality of surgical cooperation^[13].

1.3.3. Quality control circle

A quality management group spontaneously formed by operating room nursing staff, which uses professional quality control tools to focus on the pain points of clinical work, and realizes the continuous improvement of nursing quality through full participation, division of labor, and cooperation, and cyclic improvement^[14].

2. Materials and methods

2.1. General materials

This study was a quasi-experimental study with self before-and-after comparison, approved by the Medical Ethics Committee of the hospital (approval number:2024-YX-036), and all research objects provided informed consent. A total of 13 robot-assisted pancreaticoduodenectomy surgeries completed in the operating room of our hospital from May to June 2025 (before QCC activities) were selected as the control group, and 13 homogeneous surgeries from August to September 2025 (after QCC activities) as the observation group. Inclusion criteria: (1) all surgeries were diagnosed as pancreatic head cancer or periampullary cancer, and simple robot-assisted pancreaticoduodenectomy was performed; (2) the chief surgeon team, anesthesiology team and equipment conditions were completely consistent; (3) the rotating nurses involved in cooperation had less than 1 year of working experience, had not received standardized professional training for robotic surgery, and had no cooperation experience in similar surgeries; (4) the whole surgical process was smooth without special circumstances such as conversion to open surgery and major complications. Exclusion criteria:(1) emergency surgeries and complex surgeries with combined resection of other organs; (2) rotating nurses who had participated in robotic surgery cooperation or special training in the past; (3) cases with incomplete clinical data and inability to complete the whole inspection. A total of 12 rotating nurses were included in the two groups, all of whom were female, aged 24–32 years, with an average of (28.3±0.8) years; 10 with a bachelor's degree and 2 with a master's degree; the working time in the operating room was 2–10 years, with an average of (5.2±1.5) years. There were no statistically significant differences in general data, such as age, educational background, working years, and basic theoretical assessment scores of rotating nurses between the two groups ($P>0.05$), with comparability.

2.2. Implementation methods of quality control circle activities

2.2.1. Establishment of quality control circle team

Following the principles of voluntary participation, complementary advantages, and clear rights and

responsibilities, a special QCC team of 15 members was established, including 1 chief nurse and 1 ward nurse as supervisors to control the activity direction and coordinate resource support; a senior nurse in charge with 10 years of operating room nursing experience and more than 3 times of QCC leading experience was selected as the circle leader to overall plan the whole activity process and decompose task nodes; a nurse specialist good at data statistics, chart making and document sorting was selected as the circle secretary to be responsible for data collection, data archiving and progress reporting; the remaining 12 circle members included 3 N3-level specialist nurses, 4 N2-level backbone nurses, and 5 rotating nurses participating in the study. A kick-off meeting for circle members was held to clarify the job responsibilities and division of labor of each position, and an exclusive work group was established to ensure real-time communication. The circle name “Precision Circle” was determined by voting, the circle spirit “Precise Cooperation, Safety Escort, Lean Quality Control, Continuous Improvement” was condensed, and an exclusive circle emblem was designed to strengthen team cohesion.

2.2.2. Theme selection

Using the brainstorming method, combined with the annual quality control focus of the operating room, the training pain points of rotating nurses and the clinical work difficulties, 4 alternative themes were initially screened: “Improving the standardization rate of robot-assisted pancreaticoduodenectomy cooperation”, “Reducing the loss rate of robotic surgical instruments”, “Shortening the preoperative preparation time of complex surgeries”, and “Improving the satisfaction of medical and nursing coordination in the operating room.” All circle members were organized to score anonymously according to four evaluation indicators of importance, feasibility, urgency, and circle capability (1–10 points for each item, for a total of 40 points). After eliminating invalid votes, the average score was counted. Finally, “Improving the standardization rate of robot-assisted pancreaticoduodenectomy cooperation among rotating nurses in the operating room” was selected as the research theme with the highest score of 36.8 points. This theme is in line with clinical needs, has great room for improvement and strong quantifiability, and meets the dual objectives of department quality control and talent training.

2.2.3. Formulation of activity plan

A detailed activity schedule was formulated using a Gantt chart, specifying the activity cycle from April 1 to September 30, 2025, and strictly dividing four stages in accordance with the PDCA cycle: the planning stage (P, April 1 to May 19), completing the team establishment, theme selection, current situation investigation, root cause analysis and countermeasure formulation; the implementation stage (D, May 20 to August 7), promoting the implementation of various rectification countermeasures, and carrying out hierarchical training and process optimization; the check stage (C, August 8 to August 29), collecting data of the observation group, comparing the rectification effects, and verifying the implementation of countermeasures; the action stage (A, September 1 to September 30), summarizing successful experiences, formulating standardized documents, sorting out remaining problems and incorporating them into the next round of quality control cycle. Clear time nodes and responsible persons were set for each stage, and a weekly progress review meeting was held to adjust deviations in a timely manner and ensure the orderly progress of activities.

2.2.4. Grasp of current situation

By consulting the Chinese Expert Consensus on Nursing Cooperation in Robotic Surgery (2024 Edition),

Guidelines for Nursing Practice in Operating Room (2024 Edition), and relevant high-quality literature, combined with the operational characteristics of robot-assisted pancreaticoduodenectomy in the hospital, the Inspection Form for the Standardization of Rotating Nurses' Cooperation in Robot-Assisted Pancreaticoduodenectomy was jointly formulated by surgical chief surgeons and specialist nurses^[15–16]. The scale covered 3 major dimensions of preoperative supplies preparation, intraoperative precise cooperation, and postoperative instrument processing, and was refined into 24 key inspection indicators such as supplies inventory, aseptic operation, instrument replacement, equipment control, emergency disposal, and table management. Each operation was judged by the binary criteria of “standard” and “non-standard.” Two specialist nurses trained uniformly were selected as inspectors to conduct full-process follow-up inspections on 13 surgeries in the control group, with double-checking and independent scoring throughout the process to ensure the objectivity and accuracy of data. A total of 312 operations were inspected in this study, among which 243 were standardized, with a baseline cooperation standardization rate of only 77.88%. The Pareto chart was used for statistical analysis of the distribution of non-standard items, and according to the “80/20” Pareto principle, five core problems with a cumulative proportion of 78.25% were screened out: non-standard timing of intraoperative item use, non-standard replacement of intraoperative robotic instruments, non-standard emergency cooperation for intraoperative bleeding, non-standard handling of robotic equipment failures, and non-standard zonal management of intraoperative supplies, which were identified as the key improvement objectives of this activity.

2.2.5. Root cause analysis

All circle members were organized to hold a special analysis meeting, and the fishbone diagram was used to conduct in-depth traceability and analysis of the five core problems from four dimensions of personnel, items, methods, and environment, and decompose them layer by layer to the root causes. After multiple rounds of discussion and voting screening, 8 key root causes were finally determined: (1) fragmented professional training for rotating nurses, lack of systematic teaching; (2) no unified placement standard for preoperative instrument tables, chaotic zoning; (3) no real-time assessment closed loop after training, unable to control learning effects; (4) single function of the online learning platform, lack of learning resources; (5) no disclosure of the chief surgeon's operating habits, low fit of cooperation; (6) no posting of standardized operating procedures on the wall, no real-time reference basis; (7) inadequate training on the function keys of robotic equipment, unfamiliar operation; (8) no standardized process for instrument replacement, strong randomness. For each root cause, the circle members analyzed the influence degree and controllability one by one, and focused on the factors that could be rectified quickly with obvious effects to formulate countermeasures.

2.2.6. Formulation and implementation of countermeasures

Targeting the 8 root causes, the brainstorming method was used to diverge thinking, and 12 improvement countermeasures were initially formulated. All circle members scored from four dimensions of feasibility, economy, timeliness, and circle capability (1–5 points for each item, for a total of 20 points), and eliminated inefficient countermeasures with scores lower than 15 points. Finally, 6 core countermeasures were determined, with clear responsible persons and implementation time limits for accurate implementation of rectification:

- (1) Implementation of standardized surgical table setting: jointly demonstrated with the robotic specialist group and surgical doctors, formulated a standardized placement scheme for instrument tables in robot-assisted pancreaticoduodenectomy. In accordance with the principles of “access nearby, zonal management, and asepsis first”, the instrument area, consumable area, emergency supplies area, and spare supplies area were divided. High-definition demonstration diagrams were taken, and placement flow charts were made. Special training and practical operation assessment were organized for rotating nurses, requiring all staff to master proficiently and implement uniformly throughout the process.
- (2) Construction of a closed loop of training and assessment: a closed-loop training mode of “theoretical teaching + practical operation drill + real-time assessment + wrong question review” was established. Within 48 hours after each special training, online theoretical tests and offline practical operation assessments were carried out, and only those who passed the assessment could participate in surgical cooperation; those who failed received one-on-one supplementary training and a second assessment until they met the standards, eliminating the phenomenon of “training without assessment and disconnection between learning and application”.
- (3) Upgrading of the online learning platform: the original scattered learning resources on WeChat Work were migrated to the DingTalk Cloud Classroom to build an exclusive learning column. Standardized operation videos, expert consensus, surgical process courseware, error point analysis, and other resources were uploaded, and functions such as speed playback, offline download, and online Q&A were opened to support rotating nurses in fragmented autonomous learning and consolidate professional knowledge at any time.
- (4) Carrying out multi-mode integrated training: a three-dimensional training mode of “workshop practical operation + surgical follow-up training + scenario simulation drill” was adopted. The chief surgeon was invited to give a special explanation on surgical steps, operating habits, and cooperation needs; senior specialist nurses were arranged for one-on-one training with on-site error correction and guidance; emergency scenarios such as intraoperative bleeding, robotic arm jamming, and instrument failure were simulated to carry out practical operation drills and improve emergency cooperation capabilities.
- (5) Posting and publicizing standardized processes on the wall: standardized documents such as the Manual of Cooperation in Robot-Assisted Pancreaticoduodenectomy, Aseptic Operation Specifications for Robotic Arms, and Intraoperative Emergency Disposal Process were compiled and sorted out. Acrylic display boards were made and posted in prominent positions, such as the walls of the operating room and the nurses’ station, facilitating rotating nurses to consult and standardize operations at any time during surgery and reducing memory deviations.
- (6) Making practical operation videos of instrument replacement: specialist nurses demonstrated the whole process of disassembly, replacement, and installation of robotic instruments, marked key operation points, aseptic precautions, and time control requirements. A 10-minute high-definition practical operation video was shot and uploaded to the learning platform, requiring rotating nurses to watch repeatedly and simulate practical operations to standardize the instrument replacement process.

2.2.7. Effect verification

After the implementation of the countermeasures, the effect verification stage was entered. Using the same inspection form, inspectors and judgment criteria as in the current situation grasp stage, full-process follow-

up inspections were conducted on 13 surgeries in the observation group. The time consumed in preoperative instrument table preparation, the number of intraoperative cooperation errors, and the satisfaction scores of medical staff were recorded simultaneously. The data of the two groups were compared to quantify the rectification effects, verify the improvement of core problems, and evaluate the goal achievement.

2.2.8. Statistical methods

SPSS 22.0 statistical software was used for data analysis. Measurement data conforming to a normal distribution were expressed as (Mean \pm SD), and an independent sample *t*-test was used for comparison between groups; count data were expressed as the number of cases and percentage (%), and χ^2 test was used for comparison between groups; rank data were tested by the rank sum test. $P < 0.05$ indicated a statistically significant difference, and $P < 0.01$ indicated a highly statistically significant difference.

3. Results

3.1. Comparison of the standardization rate of surgical cooperation between the two groups

A total of 316 operations were inspected in 13 surgeries of the observation group, with 309 standardized operations, and the standardization rate of surgical cooperation reached 97.76%; 312 operations were inspected in the control group, with 243 standardized operations, and the cooperation standardization rate was 77.88%. The cooperation standardization rate of the observation group was significantly higher than that of the control group, with a highly statistically significant difference ($\chi^2 = 58.326$, $P < 0.001$), showing a prominent effect of quality improvement.

3.2. Comparison of surgical efficiency indicators between the two groups

The time for preoperative instrument table arrangement and preparation in the observation group was (8.5 \pm 1.2) minutes, and that in the control group was (15.3 \pm 2.1) minutes, with the time consumed in the observation group significantly shortened and a statistically significant difference ($t = 12.634$, $P < 0.001$); only 1 case of intraoperative cooperation-related errors (including supplies omission, operational errors, and cooperation lag) occurred in the observation group, with an incidence rate of 1.54%, while 2 cases occurred in the control group, with an incidence rate of 15.38%, and the incidence rate of errors decreased significantly ($\chi^2 = 4.215$, $P < 0.05$).

3.3. Improvement of core problems

After the implementation of QCC rectification countermeasures, the occurrence frequency of the five core non-standard problems decreased significantly: non-standard timing of intraoperative item use decreased from 28 times to 3 times, non-standard instrument replacement from 22 times to 2 times, non-standard emergency cooperation for intraoperative bleeding from 15 times to 1 time, non-standard handling of robotic equipment failures from 10 times to 0 times, and non-standard supplies management from 14 times to 1 time. The overall improvement rate of core problems reached 92.3%, and the cooperation shortcomings were completely made up for.

3.4. Comparison of medical and nursing satisfaction

A self-made satisfaction scale for medical and nursing coordination in the operating room (full score of

5 points, higher score indicating higher satisfaction) was used for anonymous investigation of the chief surgeon, first assistant surgeon, and circulating nurse. The results showed that the satisfaction of all positions in the observation group was significantly higher than that in the control group, with a highly statistically significant difference ($P<0.001$), as shown in **Table 1**.

Table 1. Comparison of medical and nursing satisfaction scores between the two groups (Mean \pm SD, points)

Evaluation object	Control group	Observation group	<i>t</i> value	<i>P</i> value
Chief surgeon	3.4 \pm 0.3	4.6 \pm 0.2	18.725	<0.001
First assistant surgeon	3.5 \pm 0.4	4.8 \pm 0.1	21.368	<0.001
Circulating nurse	3.5 \pm 0.3	4.8 \pm 0.2	20.547	<0.001

3.5. Goal achievement

Combined with the circle capability score and the proportion of improvement focus, the target value of this activity was calculated to be 93.81%, and the actual achieved cooperation standardization rate was 97.76%. Calculated by the formula: goal achievement rate = (actual value - current value) / (target value - current value) \times 100% = 105.02%, progress rate = (actual value - current value) / current value \times 100% = 25.53%. The preset quality control target was exceeded, and the improvement effect was beyond expectation.

4. Discussion

4.1. QCC activities accurately solve the cooperation problems of rotating nurses and improve the level of nursing quality control

Robot-assisted pancreaticoduodenectomy has complex processes and many cooperative links. Due to a lack of experience and insufficient training, rotating nurses are prone to non-standard cooperation problems, which have become a weak link in the nursing quality control of the operating room ^[17]. This study abandoned the traditional extensive training mode through QCC activities, used the Pareto chart to accurately locate core problems, and used the fishbone diagram to deeply explore the root causes, avoiding the blindness and formalization of rectification countermeasures. Through targeted measures such as standardized table setting, closed-loop assessment, and multi-mode training, the problems of unfamiliar operation, unclear processes, and disconnection in cooperation of rotating nurses were solved from the root, and the standardization rate of surgical cooperation was increased by nearly 20 percentage points, far exceeding the preset target. This result is consistent with the research conclusion of Yu Xiaofen et al. on modular training improving the quality of robotic surgery cooperation, confirming that the scientific and systematic quality control mode of QCC can effectively improve the professional ability of rotating nurses and lay a solid foundation for the nursing quality of the operating room ^[18].

4.2. Optimization of standardized processes shortens surgical time and reduces perioperative risks

Preoperative preparation efficiency and intraoperative cooperation fluency directly affect the surgical progress and patient safety. Prolonged surgery will increase the patient's anesthetic risk, infection risk, and stress response ^[19]. This study completely changed the randomness of rotating nurses' "operation by feeling and preparation by memory" by formulating a unified table setting standard, posting process guidelines on

the wall and standardizing the instrument replacement process, realizing the orderliness of preoperative preparation and the standardization of intraoperative cooperation, greatly shortening the time consumed in instrument table preparation, and reducing the incidence of intraoperative cooperation errors to 1.54% at the same time. The combination of the online learning platform and scenario simulation training enables rotating nurses to consolidate their skills in fragmented time, quickly familiarize themselves with the surgical rhythm and equipment operation, and further improve their cooperation fluency. It not only reduces the work pressure of nurses but also builds a strong safety defense line for the smooth development of surgery, realizing the double improvement of nursing efficiency and safety.

4.3. Improvement of medical and nursing coordination satisfaction and construction of a benign working atmosphere in the operating room

The efficiency of medical and nursing coordination in the operating room is directly related to the surgical quality and team morale. Non-standard cooperation of rotating nurses is likely to lead to repeated operations and waiting time for doctors, causing negative emotions ^[20]. In this QCC activity, the chief surgeon was invited to participate in process formulation and training teaching, enabling rotating nurses to accurately grasp the doctor's operating habits, realize "precise cooperation and supply on demand", and greatly improve the satisfaction of surgeons; at the same time, the standardized process reduces the operational anxiety of rotating nurses and the coordination workload of circulating nurses, thereby improving the internal satisfaction of the nursing team. The simultaneous improvement of the satisfaction of both medical and nursing staff effectively resolves cooperation conflicts, creates a working atmosphere of "efficient coordination and mutual help" in the operating room, and lays a good team foundation for the development of subsequent complex surgeries.

4.4. Construction of a replicable training system to boost the construction of nursing talents in operating room subspecialties

With the wide application of robotic surgery in general surgery, the reserve of specialist nurses in the operating room has become a rigid demand, and the standardized training of rotating nurses is the core link of subspecialty construction ^[21]. Through QCC activities, this study formed a complete closed loop of "training—assessment—practical operation—review—optimization", precipitated a series of reusable resources such as standardized manuals, practical operation videos, inspection scales, and table setting specifications, and constructed a targeted and implementable training system for rotating nurses. This system is not only applicable to robot-assisted pancreaticoduodenectomy, but also can be adjusted according to the characteristics of different subspecialty surgeries, such as gastroenterology, hepatobiliary surgery, and urology, providing a feasible template for the large-scale and standardized training of specialist nurses in the operating room, and boosting the discipline construction and talent echelon improvement of the department.

4.5. Research limitations and future prospects

This study has certain limitations: first, it is a single-center, small-sample quasi-experimental study with a limited sample size, and there is a certain deviation in the extrapolation of results; second, the observation period is short, only the short-term rectification effect is verified, and the long-term effectiveness needs to be further confirmed; third, the indicators such as job competence and long-term retention rate of rotating nurses are not tracked. In future research, the sample size can be expanded, multi-center collaborative research can

be carried out, and the follow-up period can be extended to evaluate the long-term effectiveness of quality control measures; at the same time, QCC can be integrated with PDCA, 6S management and other tools to further optimize the nursing process; in addition, a job competence evaluation model for rotating nurses can be constructed to realize personalized and precise training and continuously improve the nursing cooperation ability of complex surgeries in the operating room.

5. Conclusion

QCC activities use scientific quality management tools to accurately focus on the pain points of rotating nurses in the cooperation of robot-assisted pancreaticoduodenectomy. Through systematic problem analysis, targeted countermeasure implementation, and full-process quality control, it can significantly improve the standardization rate of surgical cooperation, shorten the preoperative preparation time, reduce intraoperative cooperation errors, and improve the satisfaction of medical and nursing coordination. At the same time, a replicable professional training system for rotating nurses is constructed. This mode has strong operability and a remarkable improvement effect, which can effectively ensure the safety of complex robotic surgeries, improve the nursing quality and professional level of the operating room, and is worthy of popularization and application in the nursing quality control and talent training of operating room subspecialties.

Disclosure statement

The authors declare no conflict of interest.

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Tracing the Trajectory: The Evolutionary Application and Optimisation of Blended Learning Models in Psychiatric Nursing

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Abstract: *Objective:* To review the current application status of online-offline blended teaching in psychiatric nursing courses, clarify the theoretical foundations, practical key points, and existing challenges of this teaching model, and provide references for the reform of psychiatric nursing course teaching. *Methods:* We reviewed many studies from China and other countries about blended teaching in psychiatric nursing. We focused on how the model is built, how teachers use it, its results, and the difficulties. *Results:* Blended teaching helps students learn more theory, improve practical skills, and become better at caring for patients with kindness. But there are still problems like course content not connecting well, weak technology support, and teachers needing more training. *Conclusion:* Blended teaching fits psychiatric nursing well because of the subject's special needs. We need to fix the current problems so this teaching method can be used more widely and effectively.

Keywords: Psychiatric nursing; Blended teaching; Online-offline integration; Course construction; Teaching effectiveness

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1. Introduction

Psychiatric nursing is an important part of nursing. It requires nurses to have good professional knowledge, communication skills, and psychological care abilities. In recent years, the number of people with mental health problems has continued to increase, making psychiatric nursing education more important than before. The quality of psychiatric nursing courses can directly affect nursing students' future work ability and the quality of care they provide to patients. However, traditional teaching methods still have some problems. Most classes mainly focus on teachers giving lectures and students listening. Although students can learn theoretical knowledge, they often have few chances to practice what they learn. As a result, many students

find it difficult to deal with real patients when they enter clinical settings, especially when communicating with patients or providing psychological support^[1]. At the same time, psychiatric nursing is a challenging job. Nurses not only need to care for patients with different mental health conditions but also need to cope with the emotions of patients and their family members. This often brings a lot of pressure. Therefore, it is very important for nursing education to combine theoretical learning with practical training^[2]. In recent years, nursing education in China has actively promoted the concept of “New Medical Science.” This approach encourages closer cooperation between schools and hospitals and supports the use of new teaching methods. It also aims to train nursing students with stronger professional skills and comprehensive abilities. In addition, the Undergraduate Nursing Education Standards emphasize the importance of practical ability, humanistic care, and the use of information technology in teaching. Under this background, blended teaching has become a popular teaching method in psychiatric nursing education because it is flexible and can meet different learning needs^[3]. Blended teaching combines online learning with face-to-face classroom activities. Students can study learning materials online at their own pace and then participate in classroom discussions, skills training, and clinical practice activities offline. This teaching method helps students understand knowledge more deeply and improve their practical abilities^[4]. Many studies have shown that blended teaching can increase students’ interest in learning and improve their confidence. In psychiatric nursing courses, students can first learn theories and clinical cases online and then practice communication skills and teamwork through classroom activities, simulations, and group discussions^[5,6]. Many students believe that this learning method is more interesting and helps them better understand psychiatric nursing knowledge. It is especially useful for developing communication skills, empathy, and emergency response abilities. Recent studies in medical education have also found that blended teaching can improve students’ communication skills, teamwork ability, and self-confidence. Through videos, online learning tasks, and scenario simulations, students can repeatedly practice in a safe learning environment and reflect on their performance. This helps them prepare for real clinical situations more effectively^[6,7]. In addition, blended teaching provides teachers with more ways to teach and assess students. Teachers can better understand students’ learning progress and identify problems in time. This helps improve teaching quality and strengthens the connection between classroom learning and clinical practice. Therefore, reviewing and summarizing the design, implementation, and evaluation of blended teaching in psychiatric nursing courses is meaningful. It can provide useful references for nursing education reform and help improve the quality of psychiatric nursing education and patient care^[8].

2. Teaching requirements and challenges of psychiatric nursing courses

2.1. Professional characteristics of psychiatric nursing

Psychiatric nursing is a very general area, and its professional aspects are multi-dimensional knowledge and competence. On one hand, psychiatric nursing not only explains the basic notions of mental health and mental health, but also multiple levels such as humanistic care, communication skills, crisis intervention, and ethics, placing extremely high demands on the integration of theory and practice^[9]. Students need not only to master the basic knowledge of mental disorders, assessment tools, and intervention methods but also to possess keen observation and clinical judgment skills to make scientific decisions in the complex and variable clinical environment of psychiatry^[10]. Moreover, psychiatric nursing requires that nurses care by humanistic considerations, that they know patients’ psychological needs, are friendly to them and care about

them, and that they have good nurse-patient relationships. This sets higher standards for communication skills, empathy, and self-management abilities^[9].

The main competencies of psychiatric nurses include mental disorder assessment, crisis management, patient communication and support, and professional supervision. For example, students need to systematically learn and master the assessment process for mental disorders, risk assessment and management, recognition of psychiatric symptoms, and nursing intervention techniques, enabling them to implement effective crisis interventions when patients exhibit self-harm, suicidal, or aggressive behaviors^[11]. In addition, psychiatric nursing schools are highly focused on communication skills, requiring students to be patient, understanding, and professional in conversations with patients and their relatives, and to alleviate anxious, fearful, and lonely patients to encourage recovery.

In addition to basic literacy, psychiatric nursing also suggests the use of full-fledged knowledge. Students need to possess interdisciplinary knowledge, such as psychology, sociology, law, and ethics, and be able to flexibly apply this knowledge in clinical practice^[12,13]. In the actual teaching process, combining theoretical learning with clinical training and employing diversified teaching methods such as role-playing, case analysis, and scenario simulation helps students transform theoretical knowledge into practical abilities^[10,14]. At the same time, psychiatric nursing courses also try to learn self-discovery and teamwork abilities in a group and to improve communication and coordination abilities in multi-disciplinary teams^[15].

Summarizing, psychiatric nursing courses have pros and cons with the same focus on theory and practice, with ability and literacy, and have the ability to analyze, communicate, and collaborate with humans based on the competence of having the skills necessary to cope with psychiatric nursing.

2.2. Limitations of traditional teaching models

The teaching methodology of psychiatric nursing education is usually based on teacher lectures, where students are generally passive participants and do not have the opportunity for active participation and interaction. By this approach of learning, it is not necessary to learn students' real abilities and emotions, nor is it realistic for modern nursing education to learn their full abilities. Bloom's Taxonomy of Educational Objectives emphasizes an approach to the development of cognitive, affective, and psychomotor fields. However, traditional teaching models overly focus on theoretical explanation, leading to insufficient cultivation of students' practical operation and clinical thinking abilities, affecting their future comprehensive competence in the field of psychiatric nursing^[1]. In addition to the practical aspects, training in psychiatric nursing comes with additional constraints such as venue, faculty, and patient resources. Due to a low psychiatric clinical internship duration and limited faculty and patient resources, students do not have much opportunity to gain an actual experience in clinical practice, and it is very difficult to get a deeper understanding of the core contents, such as psychiatric nursing, communication skills, and human services in practice. Research has found that single classroom lectures cannot help students deeply understand abstract concepts in psychiatric nursing, nor can they effectively enhance practical abilities such as communication, decision-making, and clinical reasoning^[5]. As a result, there is an increasing interest in developing more flexible, diverse, and student-centered teaching models to enhance students' general literacy and clinical skills.

2.3. The need for blended learning in psychiatric nursing curricula

The teaching content of psychiatric nursing courses combines theoretical depth with the complexity of

clinical practice, requiring teaching models to be flexible and adaptable to meet students' dual needs for knowledge and skills^[16]. Single-mode teaching methods are no longer sufficient for the current development of psychiatric nursing. Research points out that psychiatric nursing education faces challenges in helping students overcome stereotypes about patients with mental disorders and improving their actual care abilities, urgently needing to introduce new teaching models to promote students' correct understanding and positive attitudes towards patients with mental disorders^[17]. The blended teaching model by online and offline means can provide more space to systematically learn about theoretical knowledge and practice in practice. In-clinic courses can provide flexible learning time and resources to increase autonomous learning performance; in-clinic and online practices and interactive sessions can be provided, such as role-playing help deepen students' understanding of theoretical knowledge and exercise their clinical decision-making abilities and emotional coping skills in real situations^[10,18].

Moreover, psychiatric nursing courses place great emphasis on students' thinking and teamwork abilities. It turns out that structured objective video scenes are better developed than structured: Objective Structured Video Examination (OSVE) and role-playing teaching methods can effectively promote the integration of theory and practice among students, enhance their clinical reasoning and self-assessment abilities, and simultaneously boost students' confidence and adaptability through simulated patient interactions^[10]. Teleprecepting is a new, additional teaching tool since it allows students to take part in various medical settings beyond geographic constraints. Particularly in specialized fields such as psychiatric nursing, online guidance and teamwork further hone students' communication and collaborative skills^[19]. Therefore, the blended teaching model not only serves the need for flexible and diverse teaching on psychiatric nursing courses but also helps us to improve students' independence, critical thinking, and teamwork skills.

2.4. Current application status of blended teaching in psychiatric nursing

Many domestic institutions have conducted practical explorations of blended teaching in psychiatric nursing, forming differentiated teaching models and implementation pathways. Typical cases are summarized as follows. See **Table 1** for details:

Table 1. Practical exploration of mixed teaching of psychiatric nursing in domestic institutions

Institution Name	Teaching Model	Online Resource Format	Offline Practice Methods	Core Outcomes
Nursing School of a University of Traditional Chinese Medicine ^[20,21]	Model based on experiential teaching method, case teaching combined with mind mapping method	Classroom teaching video viewing, Classroom Pai platform, film appreciation	Scenario simulation, experience sharing (themed speeches), case analysis, social practice, clinical clerkship	Effectively improves student grades, empathy, and teaching quality
Nursing School of a Medical University ^[16,22]	Model based on BOPPPS teaching model / "Online theory + Offline" blended model	Modular courses (videos, cases, assessments) provided by smart education platforms	Scenario simulation, case discussion, and clinical training	Effectively stimulates student interest and confidence, and compensates for the shortcomings of traditional teaching through multi-dimensional interaction and contextualized teaching

Institution Name	Teaching Model	Online Resource Format	Offline Practice Methods	Core Outcomes
Nursing Department of a Vocational and Technical College ^[23]	Model based on SPOC + DingTalk group blended model	Smart Vocational Education Cloud platform courses, DingTalk online Q&A	Targeted review, reflection, and preview arrangements, evaluation of teaching and learning, etc.	Improves students' autonomous learning ability, increases their enthusiasm and participation in the course, enhances online teaching quality, and simultaneously raises their willingness to work in psychiatry

In both cases, the blended teaching in home institutions is digitalized, contextualized, and heterogeneous, but different levels of practice are observed between institutions of different levels. Undergraduate institutions place more emphasis on the application of virtual simulation technology and the cultivation of higher-order thinking skills, while vocational colleges tend to focus on job skill training and school-enterprise collaborative education^[24].

3. Theoretical foundations and construction pathways for blended learning models

3.1. Theoretical foundations of blended teaching

Blended teaching in psychiatric nursing is mostly based on two theories. One is constructivist learning theory, and the other is adult learning theory. These theories help us build the online and offline mixed teaching model. Constructivist theory believes students should build knowledge by themselves instead of just listening. They learn better when they interact with others, do things actively, and think about what they have done. In psychiatric nursing classes, teachers often use case studies, role-playing, group discussions, and educational films. These activities really help students connect what they learn from books with real nursing work^[25]. For example, students first look at theory videos online at home. Then in class or hospital practice, they do simulations with fake patients. This combination works well and improves their thinking and practical skills^[26]. The other theory — adult learning theory — says that grown-up students learn best when the content is useful for their real life and they can control their own study. Most students in psychiatric nursing are already in higher grades or graduate level. They have some hospital experience and know how to manage their time. They want to learn things that can help them in future jobs. So blended teaching is very suitable for them. Students can watch videos whenever they want, read materials at their own speed, and then talk with teachers and classmates during offline classes. This way, they slowly mix theory with real practice. After doing practice, they are encouraged to think about what they did, which helps them get better at communication, empathy, and making decisions. In short, these two theories are very important for blended teaching in psychiatric nursing. They make students more active in learning and help them practice skills many times.

3.2. Construction elements of the blended teaching model for psychiatric nursing courses

The blended teaching model uses both online and offline classes to help students improve theory and

practical skills at the same time. For the online part, teachers use MOOCs, short videos, and simulation tools. These are good for teaching basic knowledge, discussing cases, and doing some interactive activities. Some studies found that watching videos and doing online learning can make students more confident when facing psychiatric nursing problems. They become better at understanding symptoms like delusions, show more empathy to patients, and learn to work in teams ^[5]. Online tests based on real problems also help students think more deeply and connect knowledge with actual clinical work ^[27]. For the offline part, students do more hands-on practice. They use role-playing and scenario simulations to experience real situations. This helps them improve communication skills, empathy, and the ability to make decisions quickly. It also lets them apply what they learned in class to difficult patient cases ^[10,28]. Through these practice activities, students can think about what a nurse should and should not do, reflect on their own actions, and get better at working with others. These things are very important for becoming a good psychiatric nurse ^[29]. Generally speaking, online classes are used for theory and case discussion because it is convenient and saves time. Offline classes are better for skill training, learning how to handle emotions, and building professional qualities. Teachers should check students' progress throughout the whole course using exams, case reports, skill tests, and learning journals. When online and offline parts are well combined, and different evaluation methods are used, the teaching quality becomes better and the whole model can keep improving ^[6,10,27].

3.3. Teaching team and management mechanisms

To do blended teaching well in psychiatric nursing, we need a good teaching team and proper management. It is better to have different kinds of professionals in the team, such as psychiatrists and experienced nurses. This team can give students both theory knowledge and real practical skills. For example, when doing simulations or case discussions, psychiatrists can help students recognize difficult mental symptoms, while nursing teachers teach them how to provide care and talk with patients. When everyone works together, the teaching becomes much more practical and useful for students ^[30]. Also, to work in a multidisciplinary team, students can better understand team ownership and practical performance of their work, and better understand teamwork skills for their future work. Regarding course management and quality monitoring, there is a scientific and comprehensive management policy. On the one hand, clear teaching goals and evaluation requirements need to be defined, and course implementation has to be monitored regularly through regular teaching feedback, student self-assessment, and peer review. Online teaching data analysis services can be used to monitor students' learning progress and participation in real time, quickly find problems that are taught and improve. On the other hand, course quality monitoring should focus on professional teachers' training. Regularly organizing teaching team members to participate in capacity-building activities such as simulated teaching and scenario drills promotes experience exchange and professional growth among team members ^[31]. By team collaboration and good management, it is possible to make it possible to support the online-offline blended teaching model of psychiatric nursing courses without losing teaching effectiveness.

4. Practical application of blended learning in psychiatric nursing courses

4.1. Development and utilisation of online teaching resources

Building an online-offline blended teaching model for the psychiatric nursing course is among the top points of effectiveness in making an online teaching model more effective. For the first part, MOOCs and micro-courses in psychiatric nursing should cover the main topics such as disease knowledge, nursing, and communication. Study suggests that some of the online teaching methods such as virtual simulation, case analysis are diversified, and scenario simulation can not only compensate for the lack of clinical practice opportunities but also significantly improve students' problem-solving abilities, clinical thinking, and communication skills^[32,33]. Online Teaching Sites may also be used for learning some ideas, or practice in a similar way. Teachers can concretize abstract psychiatric nursing theories by recording high quality course videos, designing online tests and situation situations, thereby enhancing students' understanding and application abilities^[34,35,36].

And if there is sufficient enough of a learning community, we also promote teacher-student interaction as well as peer communication. The online learning community will share and discuss hard problems, and teach and motivate students. Research indicates that in an online environment, teachers can effectively stimulate students' active learning and deep engagement through caring communication, role modeling, and emotional investment, creating a positive learning atmosphere^[37]. Meanwhile, through group discussions, collaborative tasks, and peer assessments, students can collectively solve problems encountered in learning, improving teamwork and communication skills^[33]. Online communities can be constructed with learning management (e.g. Moodle) to manage course resources with centralized knowledge, automatically track learning progress, and provide immediate feedback on learning results, thereby providing technical support for personalized teaching and differentiated guidance^[38].

Finally, online teaching resources for psychiatric nursing should focus on scientific content, variety of forms and interaction. Through MOOCs, micro-courses and virtual simulations as well as on-line collaborative learning communities, online learning will not only be possible within the time and space constraints of traditional teaching but will also lead to improvements in the professional skills of students and knowledge, paving the way for more accurate implementations of the blended teaching model.

4.2. Innovation and optimisation of offline practical teaching

In-person practical teaching is a crucial component of psychiatric nursing in the long run, and it should encourage students to think better, adapt, and practice. In recent years scenario simulation based on real cases has proved to be an effective approach for improving students. Real psychiatric clinical cases could be modelled as patients to role-play and manage emergencies in an environment of safe and controlled settings that enable students to make better decisions with regard to clinical reasoning and self-confidence. For example, standardized patient simulation helped to improve students with regard with learning satisfaction and self-confidence. Students think that this simulation environment is real, practical, and safe, contributing to the cultivation of critical thinking and decision-making abilities^[39]. In addition to scenario simulation, scenario simulation can be used to encourage theoretical knowledge

and practical operation, enhancing students' communication and adaptability in complex mental health situations^[10].

Organizing psychiatric clinical practice and training nurses. Clinical practice allows students to chat with real patients and understand better how mental disorders are treated and communicated. Recent studies show that face-to-face clinical practice helps students to overcome fear and discomfort of psychiatric practice, gradually building professional confidence and positive career identity^[40,41]. In terms of skills training, adopting diversified teaching methods such as role-playing and OSVE not only improves students' clinical reasoning and self-assessment abilities but also enhances their emotional engagement and adaptability through simulated interactions with real patients^[10,42].

Besides the above, practical teaching of psychiatric nursing always introduces new ideas such as nursing skills boot camps, simulation and group discussions. For example, psychiatric nursing skills Boot Camps use the fishbowl method, simulated sounds and learning cafés to increase students' empathy and to reduce stigmatising attitudes towards people with mental disorders^[43]. During instruction, teachers share patient's clinical case sharing, reflection, and role playing to make the students more professional and ethical and make them more conscientious to care for them^[44,29].

In summary, on-line practical teaching at Psychiatric Nursing course could be beneficial for students to make better decisions about their clinical thinking, flexibility, and practice, with situations simulation, clinical internships, and diversified skills, thereby increasing student understanding and practice as well as high confidence in psychiatric nurses' practice.

4.3. Integration and dynamic adjustment of the teaching process

In the online-offline blended teaching model of the Psychiatric Nursing course, teaching interactions and dynamic adjustment are performed to increase teaching efficiency and meet students' needs. Learning data may reveal the learning performance of the teaching levels in the online, e.g., accessing on-line learning sites, completing assignments, discussing, etc., so that online/offline teaching content and speed can be varying. For instance, it is observed that in blended teaching models students learn to balance and resolve online and offline teaching. From student learning data, teachers can instantly discover difficulties that student students may face in a particular stage and adjust their teaching content, such as increasing on-line resources or adapting offline topics to students' learning needs^[45].

Also feedback and personalized instruction. Full-texting can offer teachers with multiple feedback channels, like online quizzes, assignments and conversations. On-line assessment with student learning, teachers can provide periodic tests and personalized tutoring. Research showed that dynamic changes and personalized teaching based on data analysis can improve the motivation for students to learn self-regulation and self-confidence. In the study on self-regulated learning behaviour, cluster analysis of students' behavior on-line learning revealed that students' learning strategies and goals are changing as they come up in courses. Teachers adjusted teaching strategies accordingly, effectively promoting student learning outcomes^[46].

By the above dynamic adjustment and integration, blended teaching may adapt better to the difficulty of the Psychiatric Nursing course and the differences of students for teaching purposes.

5. Evaluation of blended teaching effectiveness and existing problems

5.1. Teaching effectiveness evaluation indicators and methods

Evaluation of teaching quality for the online-offline blended teaching model in Psychiatric Nursing requires a multi-level and heterogeneous evaluation system in order to evaluate students' learning and ability improvements. Knowledge is also a major component of evaluation systems measured through course theory exams, online exams and classroom questioning. Research has showed that VR simulation teaching in psychiatric nursing schools can help students higher on theory knowledge than traditional teaching^[47]. In addition, some teaching models (like PBL, team learning and blended flipped classrooms) can also improve students' theoretical and practical performances^[48,49].

The second critical part is skill operation ability. The skill is often measured using scenario simulation, SP training, and internship. Standard patient simulation can be used to improve students' abilities in coping with difficult mental health situations as well as to improve their practical skills and thinking^[50,39]. The development of VR and virtual simulation platforms provide an opportunity to objectively evaluate skill operation capabilities to continuously train and assess students' behaviors and emergency responses in a safe environment^[47,51].

Communication and humanistic care are all desirable characteristics of psychiatric care and often teacher and student, peer, performance or journaling. A multi-evaluation model helps students to describe their development and failure in communication and human care from multiple perspectives.

In terms of evaluation type, blended teaching model provides formative and summative evaluation. Formative evaluation is pre-class, classroom participation, online discussion, periodic assignments and skill evaluation. Sective evaluation is final theoretical and skill evaluations, general ability evaluations, etc. Multi-dimensional assessment usually uses quantitative indicators (e.g., exam scores, operation scores, etc.) and qualitative indicators (including reflective reports, clinical survey, satisfaction survey) for evaluation, scientific rigor and completeness of evaluation^[52,53]. Additionally, information technology tools (e.g., online teaching and intelligent assessment) are being deployed to teaching effectiveness assessment (eases and efficiencies in evaluation)^[54,55].

To conclude, improving blended teaching performance for psychiatric nursing needs a multi-dimensional indicator system consisting of knowledge, skills, communication, and humanistic care. It may also need multiple evaluation techniques, such as self-assessment, peer evaluation, teacher evaluation, and clinical performance, in order to gain overall positive, objective, dynamic feedback for student learning outcomes, which can be used as a scientific ground for continuously optimized teaching models and students' skills.

5.2. Analysis of the advantages of blended teaching

The blended teaching model, which combines online and offline teaching, has many advantages for psychiatric nursing courses. Firstly, blended teaching might increase the students' knowledge and practice. Systematic reviews and meta-analyses show that the nursing students who take blended courses improve their knowledge and skills more than those who teach either on a traditional or purely online basis, particularly in knowledge acquisition (standardized mean difference = 0.73) and skill training (standardized mean difference

= 0.86)^[56]. The critical thinking ability and mental health can also be enhanced by blended teaching and students generally like the teacher. Similarly, research in the field of psychiatric nursing finds that innovative blended teaching designs (such as flipped classrooms, case discussions, role-playing, etc.) not only optimize students' academic performance but also effectively reduce learning task burden and improve learning efficiency^[57].

Second, teaching improves students' self-guided learning. Students can learn online for their own learning, rely on rich digital resources for self-testing and consolidation, and bring more learning momentum and self-management^[58,59]. For example, blended teaching based on Small Private Online Courses (SPOCs) has improved students' independence and motivation in medical courses, resulting in improved performance^[60]. Besides a blended teaching, students' learning motivation, participation, and satisfaction are all enhanced with invested attention towards self-driving learning^[45,61].

Blended teaching, allowing students to "self- manage their professional status and human behavior." Offline teaching, facilitating students to systematically learn theory and by practice, case studies and peer interaction and feel professional status or humanistic. Students learn about the issues and challenges in psychiatric nursing and are more sensitive to the patients' psychological and social needs and to their professional prestige or humanism. Moreover, blended teaching creates a multi-dimensional interaction between teachers and students and students with an encouraging learning environment and team spirit^[62].

In summary, blended teaching model, both online and off-line, with better teaching design and learning may be useful not only for students' theory and knowledge, self-directedness, professional identity and awareness of humanistic care, but also for high-quality students of psychiatric nursing.

5.3. Main problems and challenges

There are some issues and challenges with the online-offline blended teaching model of psychiatric nursing courses. Among them is that it is the hardest task of the teaching team to develop and maintain online teaching resources. Course content needs to be updated due to clinical realities and student requirements, the stability, interactivity and diversity of the technological platform require a great amount of human and material investment. Other issues and challenges are that the teachers need to be professional, and they need to have been trained in the knowledge of information technology to teach in an effective manner. This is an especially challenging task for some teachers with long teaching experience and little experience with information technology. And the technical support of teaching platforms is also important to maintain the smooth pace of teaching activities.

Second, students' self-discipline and learning motivation. In a blended teaching model, students need to complete a relatively large number of online learning tasks under relatively free supervision. Some students do not have self-management skills, such as low motivation and late time. Some students are unable to learn from a new teaching session (like roleplaying and case analysis) in which they do not take part.

Third, the teachers are not enough. However, thanks to the domestic context, this results also have local meaning, namely: inadequate institutional support (most universities do not provide funds or policies

to support blended teaching, so they do not invest enough in infrastructure to support blending teaching), students knowledge (urban vs rural students have older ages than rural students) and low clinical teaching resource (high-quality hospitals in first-tier cities are very resource-rich, and remote schools do not have internship opportunities and do not yield proper teaching equity). Local issues, as well, also raise issues about implementing blended teaching and which policies and resources have to be adopted.

Finally, we are still developing our evaluation system for blended teaching. Evaluation criteria, weight allocations, and linkers between online and offline teaching are some things that need to be better optimized. Current evaluation works are focused on knowledge acquisition instead of improving the students' overall qualities, such as real-world operation and communication. However, it is still hard to bring in and easily link online and online teaching content, and the scientific rigor and clarity of teaching effectiveness evaluation need to be improved. Therefore, more efforts are needed in teaching resource building, teacher training, student management, and evaluation systems to support the overall development of the blended teaching model in psychiatric nursing.

6. Conclusion

As medical education models evolve, it is becoming critical to improve the online blended teaching model of psychiatric nursing courses. As seen by the systematic review in this paper, blended teaching not only alleviates the gap in knowledge transmission, in practice and in teaching, and among teachers, but also enables students to learn more flexible and personalized learning paths. The availability of free courses and in-person learning of online courses allow students to fully learn theoretical knowledge from themselves, and online practice training and interaction also allow students in practice to apply theory to situations in real life.

Subjective and practical results of the blended teaching model have been shown to be highly informative, self-directed, and clinical comprehensive for psychiatric nurses. Recent results have shown that in a blended teaching, students are not only able to improve their theoretical score, but they are able to make major improvements with regard to communication, critical thinking, coordination. The blended teaching approach can bring a high quality psychiatric nurses' talentedness and practical ability, as well as the potential for versatile abilities in modern medical education.

However, as a systematic teaching tool, blended teaching has a number of issues in practice. One is not sharing the teaching resources, making digital teaching papers and case libraries, some teaching staff are not able and capable to make the new model systematic enough to support systematic training and support of the teaching staff. The students come from self-discipline and information-information communities. Some students cannot adapt to blended learning which has a negative impact on teaching performance.

Different studies may make different contributions as to how to develop this work in a continuous manner; some of them emphasize that blended teaching will increase the learning success, while others suggest that over-reliance on online teaching will reduce the emotional information and immediate feedback between teachers and students. Therefore, courses should combine disciplinary characteristics and students'

needs, adapt the online versus offline portion of teaching, balance theory/practice, and maximize the full benefits of blended teaching.

Blended teaching is a new teaching model for psychiatric nursing courses. It has to be approached to provide solutions to challenges in order to allow the continuous optimization and use of this model for clinical nursing education. Examples include: better teacher training, more technical assistance for online resources, better course content integration (e.g., integrating online theory modules with offline practice), and regular teaching effectiveness tests to further improve the model. Policies: governments and educational institutions should provide effective policies, such as funding for digital infrastructure development, providing guidelines for blended teaching standards, and encouraging school-enterprise collaboration to improve the sharing of clinical practice resources, and thereby adapt to the reform requirements of “New Medical Science” education.

Future work in psychiatry is still to come. Research authors suggest that high-quality courses, learning resources, and a wide teaching evaluation system can be achieved to improve course and teaching quality. Alongside higher training and support for teaching students, better information understanding and new teaching abilities are also needed at the policy level. Top-level design can improve the sharing and sharing of quality resources, as well as ensure institutional policies that encourage blended teaching to thrive. Future work can also be developed to address the trend of intelligent transformation of psychiatric nursing education: for instance, using AI-based personalized emotion recognition training in online courses. As AI affective computing technologies mature (e.g. emotion recognition models based on face expressions, natural language processing, physiological signals), personalized online training systems can be designed for psychiatric nursing students: real-time monitoring of students’ emotional states (anxiety, frustration, empathy fatigue, etc.) during simulated communication and providing personalized feedback and interventions (eases, cognitive restructuring, or dynamic shifting of virtual patient emotions). Future randomized controlled trials may compare the long-term benefits of AI-enhanced blended teaching with traditional blended teaching in reducing clinical anxiety and improving real communication performance, tackling ethical problems.

Overall, developing and developing the blended teaching model for psychiatric nursing courses is both a natural choice for a more modern medical education as well as a chance for psychiatric nurses to develop more talent. Only by studying theory, experimentation and mechanism can there be high sustainable development for psychiatric Nursing training, providing excellent talent support for mental health and public health.

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Application Research of Virtual Cases Based on Generative AI (such as Large Language Models) in Clinical Reasoning Teaching for General Practitioner Training Programs

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Abstract: This article elucidates that generative AI virtual cases offer advantages such as abundant resources, strong interactivity, and timely feedback. By implementing application approaches—including establishing virtual case repositories, conducting scenario simulations, developing evaluation systems, and training instructors—it can effectively enhance the clinical reasoning abilities of general practice residency trainees, thereby providing a novel model and methodology for general practice education.

Keywords: Generative AI; Virtual case; General practice residency program; Clinical reasoning instruction

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1. Introduction

By the end of 2022, OpenAI's release of the ChatGPT-3.5 model marked a breakthrough in generative AI technologies, particularly those powered by large language models, sparking an innovation wave in the education sector and unlocking new opportunities and limitless possibilities. General practice residency training is pivotal for cultivating qualified general practitioners, with clinical reasoning skills constituting their core competency. The quality of this training directly impacts the standard of medical services provided. However, traditional clinical reasoning instruction in general practice residency training suffers from limitations such as insufficient real-world case resources and monotonous teaching scenarios. In this context, generative artificial intelligence leverages its inherent advantages to provide innovative approaches and effective tools for clinical reasoning education in general practice residency training, facilitating the advancement of medical education toward greater intelligence and efficiency.

2. Advantages of virtual cases in clinical reasoning teaching during general practice residency training

2.1. The case resources are abundant and diverse, covering a wide range of diseases and clinical scenarios.

General practice encompasses a broad spectrum of diseases, yet practical teaching often lacks sufficient resources for typical, rare, or specialized cases, making it difficult for resident trainees to gain comprehensive exposure to various diseases. The virtual case resources are exceptionally rich and diverse. The constructed case repository encompasses not only common and frequently encountered diseases such as community-acquired pneumonia and acute appendicitis, but also rare conditions, multisystem complications, and critical emergencies—including tetralogy of Fallot, diabetes mellitus complicated by ketoacidosis with pulmonary infection ^[1]. It can simulate real-world clinical scenarios, comprehensively depicting the entire process from basic medical history collection to laboratory examinations, while also detailing disease progression and simulating dynamic changes such as the advancement of chronic conditions and the exacerbation of acute illnesses. Furthermore, the virtual case library supports personalized learning by enabling the customization of cases according to students' needs, thereby catering to diverse learning requirements, broadening their diagnostic and therapeutic perspectives, and enhancing their clinical decision-making and treatment plan implementation capabilities.

2.2. Achieve highly interactive learning by simulating real-world physician-patient communication workflows

In the clinical reasoning instruction during general practice residency training, virtual cases provide a highly interactive learning experience by accurately replicating real-world physician-patient communication workflows. By employing technologies such as speech recognition and affective computing, it is possible to capture in real-time students' questioning patterns, speech rate, pitch, as well as non-verbal behaviors like eye contact and gestures. Additionally, the system can simulate patients exhibiting various emotions, including anxiety, anger, and sadness, to provide dynamic feedback ^[2]. For instance, when students lack empathy, the virtual patient may provide vague responses or demonstrate distrust, prompting students to refine their communication techniques; if students successfully establish trust, the patient will gradually disclose critical information, facilitating deeper diagnostic and therapeutic progress. The multimodal interaction design encompasses core processes such as information collection, condition notification, and treatment decision-making. It also employs branched narrative algorithms to simulate disease progression, enabling students to experience the complexity and risks of clinical decision-making through dynamic adjustments to communication strategies. Through repeated training, students' diagnostic skills, empathy abilities, and communication efficiency have significantly improved, laying a solid foundation for real-world clinical practice.

2.3. Provide real-time intelligent feedback to accurately assist clinical reasoning training

Virtual cases offer the significant advantage of providing instant intelligent feedback, enabling precise support for clinical reasoning training. After students complete the stages of history-taking, physical examination, diagnosis, and treatment decision-making during virtual case simulations, the system promptly conducts intelligent analysis of each step based on the predefined medical knowledge base and clinical guidelines. If critical information is omitted during consultation, the system will immediately

provide prompts and guidance for supplementation; if the diagnostic approach is deviated, the system will offer comparative cases and valid diagnostic criteria to assist students in understanding the error; if the treatment plan is inappropriate, the system will identify issues according to the latest guidelines and provide optimization recommendations^[3-4]. This real-time feedback allows students to correct errors promptly during operations, preventing erroneous thinking patterns from becoming entrenched. Additionally, the system generates detailed evaluation reports based on students' performance, identifying their strengths and weaknesses in clinical reasoning. These reports serve as a basis for developing personalized learning improvement plans, effectively enhancing the clinical reasoning and diagnostic-therapeutic competencies of general practice residency trainees.

3. Application pathways of generative AI-based virtual cases in clinical reasoning teaching for general practice residency training

3.1. Establish a virtual case library for general practice medicine and integrate multimodal teaching resources

The establishment of a virtual case database for general practice medicine must be grounded in authentic clinical data, with patient privacy safeguarded through anonymization processing. Utilizing natural language processing technology, unstructured electronic medical records are transformed into structured data, from which key information is extracted to generate case metadata (**Figure 1**). Furthermore, multimodal teaching resources should be integrated. Static resources include high-definition medical images (e.g., X-rays, CT, MRI), pathological images, and anatomical atlases, all supporting zooming and annotation. Dynamic resources encompass surgical videos, operational animations, and virtual patient voice responses to enhance teaching interactivity. Utilizing 3D modeling technology, interactive models can be created; for instance, a virtual liver model demonstrates anatomical structures and supports “virtual sectioning” to observe internal blood vessels. Simultaneously, by integrating authoritative medical literature databases and real-time case data, a dynamic updating mechanism is established to regularly incorporate cases of new diseases and novel therapies, ensuring the case database remains aligned with clinical practice^[5]. Taking the case of “acute heart failure complicating pregnancy” as an example, the database first presents symptom descriptions and auxiliary examination results, thereby constructing a comprehensive clinical information chain. Through the virtual consultation module, students interact with “patients”, and the system generates real-time responses tailored to the clinical condition while displaying changes in physical signs. During the virtual physical examination session, students operate a virtual stethoscope, with the system providing real-time feedback on abnormal signs. Upon entering the MDT consultation module, students select a treatment plan. The system simulates patient outcomes and provides multidisciplinary expert decision-making rationale. Upon completion of treatment, the system generates a multidimensional evaluation report and delivers targeted learning resources, establishing a closed-loop teaching system encompassing “case study-decision-making training-feedback-driven improvement.”

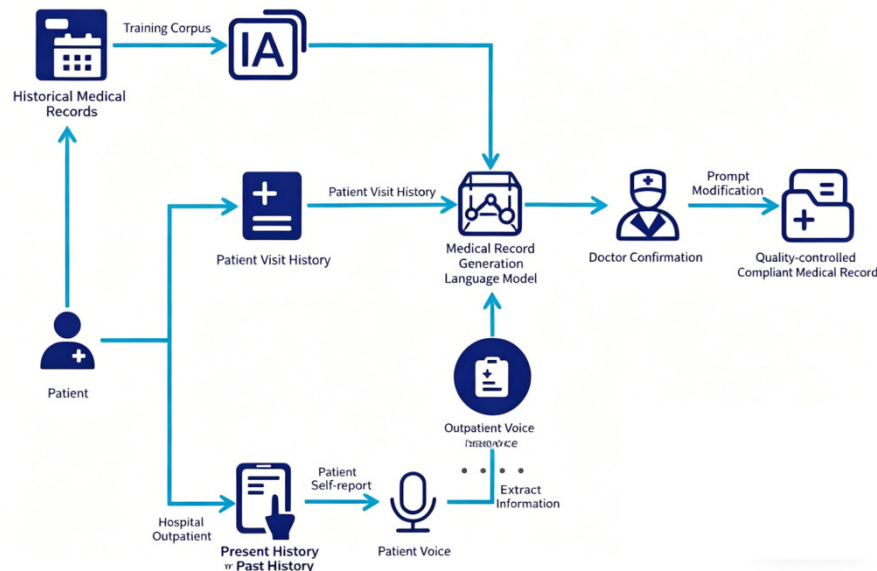


Figure 1. Digitalized medical diagnostic process based on an AI corpus

3.2. Conduct interactive case scenario simulations and implement tiered reasoning ability training

To conduct interactive case scenario simulations, it is essential to fully leverage the powerful advantages of generative AI in natural language processing and scenario generation, meticulously creating highly realistic and dynamically evolving virtual clinical scenarios. During the simulation process, the system strictly adheres to the general practice knowledge framework and clinical workflows to establish case scenarios with varying levels of difficulty and complexity. The simulation should commence with simple cases of common and frequently encountered diseases, such as community-acquired pneumonia, before progressively transitioning to complex cases involving multi-system involvement and more insidious clinical presentations, such as diabetes mellitus complicated by multiple chronic comorbidities accompanied by acute infection ^[6]. In the virtual environment, students assume the role of general practitioners and engage in real-time dialogue with virtual patients. By collecting information such as medical history, symptom characteristics, and lifestyle habits, the system utilizes generative AI to generate logical responses tailored to the patient's identity in real time. It simultaneously simulates non-verbal cues like facial expressions and tone of voice, significantly enhancing the authenticity of the interaction. Additionally, students must perform virtual physical examinations, during which the system provides corresponding clinical findings, such as pulmonary rales or heart murmurs, based on their actions, thereby assisting them in comprehensively gathering clinical data.

When implementing tiered reasoning skill training, it is essential to develop customized training programs tailored to students at different learning stages and with varying abilities. For undergraduate students, the focus is on training fundamental clinical reasoning skills. Through simple case simulations, they are guided to make preliminary diagnoses promptly based on typical symptoms and signs, integrating their acquired knowledge, and to propose basic treatment plans. The system provides timely prompts and guidance during student practice to assist them in organizing their diagnostic reasoning, such as suggesting, "The patient presents with fever and cough; which respiratory diseases should be considered?" ^[7]. As students' competencies progressively improve and they enter the intermediate training phase, the complexity

and uncertainty of case scenarios are increased, with the inclusion of misleading information and atypical symptoms. This requires students to make differential diagnoses among numerous possibilities, thereby cultivating their critical thinking and comprehensive analytical skills. For example, when simulating cases involving abdominal pain, in addition to common gastrointestinal disorders, clues related to gynecological or urinary system diseases are incorporated, enabling students to comprehensively evaluate various etiologies. During the advanced training phase, high-difficulty and complex case simulations are conducted, simulating scenarios involving multiple coexisting diseases, critical conditions, and rapid disease progression. Students are required to make accurate judgments and decisions within a short timeframe, coordinate multidisciplinary resources for comprehensive treatment, and thereby enhance their clinical adaptability and teamwork skills.

3.3. Establish an intelligent feedback and evaluation system to generate personalized learning diagnostics

Establishing an intelligent feedback and evaluation system is crucial for enabling generative AI to fully leverage its potential in clinical reasoning instruction during general practice residency training. Leveraging the deep learning and data analysis capabilities of generative AI, the system can track each operational step of students in interactive case scenario simulations in real time, assessing aspects such as the comprehensiveness of the consultation, the accuracy of physical examinations, the rationality of diagnostic reasoning, and the appropriateness of treatment plans ^[8-9]. Upon completing case management, students receive immediate intelligent feedback from the system, which clearly identifies their strengths and areas for improvement. If critical information was omitted during the consultation process, the system specifies the missing details and their significance. For diagnostic errors, the system provides a detailed explanation of the error causes based on medical databases and relevant clinical guidelines, along with the correct diagnostic methods and key differentiation criteria. Furthermore, leveraging students' comprehensive behavioral data, including case handling accuracy, decision-making speed, and proficiency in applying knowledge points, the intelligent assessment system employs scientific algorithm models to generate comprehensive, objective, and personalized learning diagnostic reports. The report not only provides feedback on students' current clinical thinking abilities and proficiency levels, but also identifies their competency gaps, such as limited understanding of rare diseases and insufficient integrative thinking skills in complex scenarios. Based on these learning diagnostic findings, the report offers personalized learning improvement recommendations and provides targeted links to learning resources. It specifically recommends relevant literature and case studies to help students address knowledge gaps and enhance their clinical thinking capabilities.

3.4. Enhance teachers' AI teaching competency training to promote the integration of virtual and real-world teaching methods

The school should establish a tiered training system, designing specialized courses tailored to different teaching stages for teachers. For novice teachers, the training focuses on fundamental operations of AI tools. Through case-based workshops, participants learn how to utilize large language models to generate typical medical cases and simulate consultation scenarios, enabling them to master key skills such as using virtual case repositories and engaging in natural language interaction. For core faculty members, advanced training is provided on integrating generative AI with clinical reasoning instruction. Through thematic seminars and project-based practices, they are guided to design blended teaching frameworks incorporating virtual cases—such as combining real patient data with AI-generated cases to create comparative teaching scenarios, thereby

fostering students' critical thinking skills^[10]. Meanwhile, a closed-loop training mechanism integrating “theory + practice + feedback” has been established. In terms of theoretical instruction, medical education experts and AI technology engineers are jointly invited to deliver lectures, elucidating the technical principles of generative AI in case generation and disease simulation, thereby helping educators clarify the boundaries and advantages of AI-assisted teaching. During the practical training phase, instructors were organized to participate in a comprehensive simulation of the entire virtual case teaching process, covering case design, student operational guidance, and outcome evaluation, thereby accumulating hands-on experience. During the feedback phase, the effectiveness of the training is regularly assessed using multidimensional data such as teaching observations, student evaluations, and teacher self-assessments, allowing for adjustments to the training content based on identified weaknesses. If deficiencies are identified in teachers' review of the medical logic in AI-generated cases, an additional course on medical knowledge graph applications will be introduced to enhance their ability to ensure the scientific rigor of these cases.

4. Conclusions

Generative artificial intelligence has brought transformative changes to clinical reasoning instruction in general practice residency training. Leveraging its robust content generation and interaction capabilities, it addresses the limitations of traditional teaching methods, enabling students to gain a richer, more authentic, and personalized learning experience. With continuous technological advancements, the application prospects of AI in medical education have become even more promising. In the future, it is essential to conduct in-depth research on how to achieve deep integration between generative artificial intelligence and general practice residency training programs, leveraging its advantages to enhance teaching quality and elevate general medical education to new heights.

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Disclosure statement

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Analysis of Existing Problems and Improvement Countermeasures in Practical Teaching of Higher Vocational Nursing

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Abstract: Practical teaching of high vocational nursing programs is essential for the cultivation of high-tech talents. Teaching and practicing are separated from clinical practice, which is currently a problem of insufficient training grounds, a lack of practical teaching skills by staff who teach the courses, and this severely restricts the output of talent with competence. The principal difficulties that cause such matters have a curriculum which is outdated compared with the work needed, as well as an unsatisfactory collaboration between schools and hospitals, which results in too simple ways of evaluating students' skills. This paper puts forward some ideas about making improvements to jobs based on abilities, integrating theories and actions, and developing skills bit by bit. Modular course content restructuring is required, double-certification faculty teams need to be built, and advanced simulation training sites must be set up. To improve on all those by enhancing the operations of the school-hospital collaborations, putting in place multiple different types of evaluations, setting aside resources for investments, which will be constantly monitored. Countermeasures are proposed to systematically increase the level of practical teaching, so as to improve students' clinical adaptability and career growth possibilities.

Keywords: Higher vocational nursing; Practical teaching; Clinical disconnect; Double-qualified teachers; Simulation training

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1. Introduction

In the world of vocational nursing, it is the responsibility of nurses to be at the forefront of things, right down by those hospitals and health institutions. Practical teaching quality is closely connected to the job and patient safety that the students have after finishing their schooling. But traditional practical teaching models are just institution-based, classroom-type training models that create a wide gap between what they learn in the school and the real needs of clinical practice. Faced with many pressures, such as the aging population,

changes in diseases, and changes and improvements in nursing service methods, educators need to change how existing training is done. Such as deepening the realism of the dilemmas faced and root cause analysis of the problem in nursing education in higher vocational nursing, and offering feasible solutions. Improving the overall standard of talent cultivated by nursing programs in schools can promote good growth on educational grounds ^[1].

2. Current problems of practical teaching

2.1. Separation between what is taught and clinical practice

A big difference exists between what one teaches in practice and actually needed during real-time when working. A lot of places are still using practical training projects and operating processes from a couple of years ago, but hospitals all around have started adopting all kinds of different technology, machines, and new guidelines. Such as school students' practice with the IV infusion, catheterization, and oxygenation exercises that are usually practiced on the standardized person or simulation dummy, but are very different in a real clinical environment when they have the changeable state of the patient's feeling, as well as psychological response, and an emergency. There are also teachers who follow set steps to show things on how to be more operational and stuff, but do not show how to make medical choices and adjust them. And this separation causes quite a few problems for students right out of college; it takes preceptors quite some time to fix their ways of doing things before these students really hit the clinic floor.

2.2. Lack of training resources

Practical teaching resources' quantity and quality cannot satisfy increasing teaching needs, making it difficult. Some vocational nursing schools have old laboratory equipment and simulation manikins that can only simulate simple clinical situations, such as lacking the ability to simulate dynamic changes in vital signs or disease development. Limited open hours for training venues, and inadequate per-student training hours and equipment usage time do not allow sufficient practice. High fidelity simulation systems, virtual reality training devices, etc., which are expensive and not commonly found. Moreover, there is a lack of timely replenishment of consumables, and some schools require students to buy their own practice materials, which has some impact on the students' learning motivation and training effect.

2.3. Lacking practicality in teachers

Lots of nurses on the high school staff do not have a lot of long-term systematic clinic working expertise. Many go straight into teaching right after college, so even if they know lots about the theory side of healthcare, it does not mean they can put all that together when it comes time to do anything practical — because actually being hands-on around real patients can have quite a different experience ^[2]. Even those with clinical experience can lose their connection with hospital technology standards and management after being absent too long from hospital settings. School-run short-term clinical training often turns out to be just a formality; it is hard for teachers to take part in every step of the whole clinical nursing process. This shortage directly shows up in class teaching with fewer lively case studies, fewer typical procedures demonstrated, and not enough teaching of how students think through things in the clinic.

3. Analysis of problem Causes

3.1. Curriculum lags job requirements

The update of the nursing curriculum systems is way slower than the development of actual clinical nursing practice. Curricula have not changed much; it is still stuck on old subject-focused setups and does not really get that fundamental nursing, medical nursing, and surgical nursing should be more related rather than completely separate parts, so there ends up being too much repeating stuff and no proper mixing across different things. While more emphasis in clinical nursing is put on those things regarding caring for others, teaching how to be healthy, and going through changes in health, along with being surrounded by many different groups, the curricula do not reflect much on any of those things. The large number of text in books and the slow publishing time makes it slow to get new stuff from textbooks to the classrooms. Emphasis in the curriculum is placed upon simply memorizing sickness facts along with step-by-step procedures, which omits the creation of high-level skills like analyzing clinical situations, predicting danger, or communicating with teams ^[3].

3.2. Ineffective school-hospital collaboration mechanism

Between schools and hospitals, the cooperation is superficial, as there is no institutionalization and no solidified and deep integration. Cooperation agreements are mostly concentrated in student internships, with very little real collaboration in developing curricula, setting standards, and sharing teachers and resources. Time and pay for hospital clinical preceptors involved in school teaching do not have institutions giving guarantees; they teach, but no one notices. School teachers cannot go to hospitals for clinical training because the hospitals restrict their teachers from doing so for safety and productivity reasons. Differences over what schools and hospitals think about cultivating talents and making evaluations get in the way of becoming one educational team.

3.3. Single teaching evaluation method

The current practical teaching evaluation system relies too much on the summative evaluation without focusing enough on formative evaluation of the learning process. The practical skills of a student would be determined by just the final marks. Assessment items remain unchanged; procedures follow standardization. Repetitive training could achieve expertise, but it cannot represent one's actual level in dealing with complicated cases. Theory exams and skill assessment are separated, not good at assessing knowledge transfer and applicability. The system lacks a proper professional soft skills measuring tool, such as communication, humanistic qualities, teamworking, and critical thinking. The evaluation subjects are singular, mostly course teachers, with little involvement from clinical mentors, patients, and students in self-peer reviews.

4. Improvement ideas and principles

4.1. Orientation towards job competency

In practice, if educators are going to reform teaching, they must have nursing work capacity as the principal logical origin, and design the educational goals and curriculum system. Job skill comprises operation ability as well as many other things, including clinical judgment, communication and collaboration, health advice, moral decision and management, and security management. Institutes need to do regular surveys on industrial

needs. Invite clinic nursing experts to join in creating, improving training courses, and making clear the main qualification require for every level of nursing post. The teaching based on competence means changing “what the teacher instructs” into “what the students will do”, thus making sure all projects, teaching cases, and evaluation criteria correspond exactly with practical jobs, so the learners can acquire what they should know for the job.

4.2. Deep integration of theory and practice

There can be no definitive sequential limit or artificial break point of theory teaching and applied learning; both need to blend naturally through all contents and times. Each lesson is taught around one of the clinical topics, forming a loop that starts with a case intro > knowledge analysis > simulation training> reflection discussion, and allows them to learn from theory by applying it to actual problems. The basics of nursing, specific nursing, and the stuff about how the body goes wrong and what drugs do should all be brought together so that students can see why things happen as they do when they are doing something on the body. The integrated design of teaching requires the breaking down of the old course walls, creating integrated theory and practice teaching books, as well as extending the period of uninterrupted time to give students ample time for their own hands-on practice and thoughts.

4.3. Tiered, progressive ability growth

Students’ professional abilities develop according to the cognitive development rules, which start from simple to complex, and then become more comprehensive. Practical teaching should correspondingly form a tiered, advancing training path. First tier: Basic skills training stage, standardize and routinize individual nursing procedures. Second tier: Comprehensive scenario simulation stage, using standardized patients and high-fidelity manikins to create complex situations such as multiple comorbidities or sudden changes in conditions, training students’ comprehensive assessment and emergency response skills. Third tier: Real clinical experience stage, using teaching hospitals to allow students to engage in actual nursing work with some responsibilities. These three tiers are connected one after another, advancing gradually, so that students can go from being a beginner to becoming a pre-nurse during their time at school ^[4].

5. Certain improvement approaches

5.1. Reorganizing modular course content

Changing the old discipline-based curricular system to many more capability units following the workflow in the hospital, as well as work activities that can commonly be done every day in a clinical setting. Each module corresponds to a type of clinical nursing situation, like the Admission Assessment Module, Perioperative Nursing Module, Critical/Emergency Identification and Management Module, and Discharge Guidance and Transitional Care Module. Integrate related knowledge, skills, and attitude goals into every single module, supplemented by a case library, video clips for demonstration purposes, and a standardized test plan. Course contents should be revised yearly with current clinical guidelines and nursing methods. The modular course can be updated quickly according to the changes in the needs of the industry, and it provides students with various options to take courses that suit them and make up for what they lack in competence, so as to adjust the contents of the lessons to the actual requirements in jobs.

5.2. “Double-qualified” teaching team construction

Create a teaching staff mechanism of college instructors who will work along with clinical adjunct instructors. Each one’s responsibility is well defined, and the methods used to do it are clearly known. The school teachers, the hospital preachers, the ones who give out the courses, give out the theoretical knowledge, teach all these basics. They provide the clinical cases, acting as the simulation scenario mentors and the internship mentors. Create a clinical teaching rotation position and choose excellent young teachers to do full-time clinical rotations in partner hospitals for more than half a year, and invite experienced clinical nurses to become associate professors to regularly participate in school teaching and research activities. Enhance standards of identification, incentive policies for dual-qualified teachers linked to title assessments and wages based on clinical work experience, and foster a structure that encourages teachers to actively cultivate their skills.

5.3. Building high-level simulation training grounds

Create a state-of-the-art nursing simulation training facility centered around instruction and training, as well as evaluation and study, by following along with the design principles and operational structures as they pertain to an actual hospital. Functional areas such as simulated wards, ICU, E.R., O.R., high-fidelity manikins, virtual venipuncture training system, emergency scenario simulation system, etc. can be found in the center so that it could give real-time data on vital signs as well as allow for manipulated disease progression. Develop a library of standard patients and typical clinical scenario cases to support multi-role, multi-stage comprehensive simulation drills. An open access policy is implemented after school in the practical training base; self-learning guidance is provided. And then at the same time build up some kind of combined real/virtual remote training environment by way of employing virtual-reality technology, this is in lieu of there being a deficiency within the number of physical training environments available, as such, educators would be able to have better teaching resources extended to those who do not reside nearby.

6. Guarantee mechanism creation

6.1. School-hospital joint operation system improvement

Develop school hospital cooperative management rules that make clear what each party is entitled to and responsible for in talent cultivation, and elevate the cooperation level from an intangible agreement into an institutional arrangement. Build up a Realistic Training Steering Board shared between the school’s academic supervisor and the hospital’s nursing section chief; convene these quarterly boards every quarter to check over main problems like subject alteration, instructor deployment, and resource assignment. Sign school-hospital joint training agreements, integrate clinical teaching into the hospital’s performance appraisal system, and give economic subsidies and title evaluation bonus points for teaching. Create a special fund for the school-hospital partnership for something like sharing educational apparatus, having teachers swap jobs with each other, improving lessons—make it so that working together is backed by the institution and given resources, and can be judged ^[5].

6.2. Setting up a multi-level evaluation system

Form a multidimensional evaluation system of knowledge, abilities, attitude, and so on, making both the sum and the development equally important. Increase subjective questions, such as case analysis and clinical

reasoning, in the theory test. Use standardized patient and scenario variables in skills assessment to look at student performance under uncertainty. Staged “skills passport” tests during learning, requiring each student to first achieve standards for one element before progressing to the next stage of training. Introduction of 360 eval by having the preceptors, classmates, the standard patients, and the student doing their own self evaluations, all going into the final grade. Electronic portfolios can be built that contain detailed documentation of materials such as practical training logs, case reflection, and operation videos that can provide data support for teaching improvement.

6.3. Mechanisms for sustained investment and dynamic monitoring

The schools have to allocate some real training budget every single year; their per pupil training cash has to go up every year too, then create this special equipment renewal pot that would ensure the simulated kit stayed as current as possible over a period of maybe three-year stretches. Create a database with practical education quality supervision data, continuously record student skills test scores, internship result reviews, license examination success proportions, and opinions from enterprises. Publish an annual practical teaching quality report, doing responsibility analysis of the problems which are found on each link. When monitoring a new discovery, start using an immediate reaction channel through the argument and experimenting before another period of educating. Sustain investment and constantly watch, make a full circle improvement ring: recognize problems, search for causes, think about solutions, and judge results.

7. Conclusion

In terms of changing practical training within higher vocational nursing programs, this kind of project has lots of complicated reasons behind it that involve different parts, like what the teachers teach, the people doing the teaching, all of the tools available to learn stuff, and places to do so, as well as methods to do things. Focus on how teaching and the clinic are disconnected with the core contradiction, analyzing the important problems related to limited amounts of resources, teachers’ capabilities, working together between schools and hospitals, along with ways to measure success. Improving job competency and integration of theory with practice, and tiered progression. Three big ways: rebuilding the course system, making a double-qualified team, and setting up some bases to help each other out; at the same time, the school-hospital work system, multidimensional assessment system, and the dynamic monitoring system come together to serve us as the conditions for carrying out this reform. Only when persisting in a problem-oriented and systems thinking approach and promoting connotative growth of practical teaching continuously, high-quality nursing talents meeting the real needs of clinical positions can be cultivated.

Disclosure statement

The author declares no conflict of interest.

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Development of a Risk Warning Factor Assessment Scale for Malnutrition in Stroke Recovery Patients

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Abstract: *Objective:* To develop a risk warning factor assessment scale for malnutrition in patients during the recovery phase of stroke, providing a basis for evaluating malnutrition risk in this population. *Methods:* Literature review and group discussions were initially used to screen potential risk factors for malnutrition in stroke recovery patients. The modified Delphi method was then employed to finalize the risk factor assessment scale. From 1st April 2022 to 1st June 2022, two rounds of expert consultations were conducted via WeChat, face-to-face interviews, and email. Data from the experts' ratings and modification suggestions for each item were recorded using Excel 2013, and statistical analysis was performed using SPSS 26.0 to determine the final risk warning factor assessment scale. *Results:* Two rounds of expert consultations were completed, with response rates (active coefficients) of 96% and 100%, respectively. The judgment basis (Ca) for the two rounds was 0.926 and 0.933, familiarity (Cs) scores were 0.800 and 0.808, and authority coefficients (Cr) were 0.863 and 0.871. The Kendall's W values for importance in the two rounds were 0.192 and 0.154 (both $P < 0.001$), while the Kendall's W values for correlation were 0.071 and 0.061 (both $P < 0.05$), indicating consistency in the experts' evaluations of the indicators. The item-level content validity index (I-CVI) ranged from 0.875 to 1.000, and the scale-level content validity index (S-CVI) was 0.977, demonstrating good content validity of the assessment scale. The final risk factor assessment scale consisted of 38 items across three dimensions. *Conclusion:* The developed malnutrition risk assessment scale for stroke recovery patients exhibits good scientific rigor and practicality, providing a reference for identifying malnutrition risks in this population.

1. Introduction

Stroke ranks first among the causes of death and disability in adults in China. Due to impaired neurological function, patients often experience dysphagia, cognitive impairment, and emotional disorders, and are prone to malnutrition^[1]. Studies have shown that approximately 20% of stroke patients suffer from malnutrition, a proportion that rises to as high as 62% by the time of discharge and in the recovery phase^[2]. Malnutrition negatively affects patients' rehabilitation outcomes and quality of life, leading to prolonged hospital stays, and is associated with poor clinical prognosis^[3–6]. Therefore, early identification of malnutrition risk in stroke patients during the recovery phase and timely individualized intervention can help facilitate successful recovery.

However, existing tools for screening and assessing malnutrition risk are mostly general-purpose instruments^[3, 7]. Moreover, the factors influencing malnutrition in stroke patients reported in the literature mostly focus on those in the acute phase, with relatively few studies targeting stroke recovery patients^[8]. This hinders the accurate identification of such high-risk patients.

As such, developing an assessment scale for identifying warning factors of malnutrition risk in stroke patients during the recovery phase is of great significance for early detection of high-risk individuals and the formulation of individualized nutritional interventions.

This study, based on the Nutritional Risk Screening 2002 (NRS 2002), aims to construct an assessment scale for warning factors of malnutrition risk tailored to stroke patients in the recovery phase through a review of the literature and a modified Delphi expert consultation method, thereby providing an effective clinical tool.

2. Methods

2.1. Establishment of the research team

The research team consisted of seven members, including one chief physician, one chief nurse, two specialized nurses, one senior nurse, and two graduate students. All nursing team members had more than five years of experience in stroke-related nutrition care and held at least a bachelor's degree or higher. The responsibilities of the research team included: reviewing relevant literature, drafting the assessment scale for warning factors of malnutrition risk in stroke patients during the recovery phase, developing the expert consultation questionnaire, selecting expert consultants, and conducting statistical analysis, discussions, and revisions based on the results of the expert consultations. This study was approved by the Ethics Committee of Hubei University of Medicine (Approval No.: 2022-RE-004).

2.2. Drafting the assessment scale prototype

Based on previous literature reports, Chinese and English search terms—including Stroke, Acute cerebrovascular event, cerebrovascular disease, Cerebrovascular accident (CVA), Cerebral infarction,

cerebral apoplexy, cerebral bleeding, Ischemic stroke, Cerebral thrombosis, Cerebral embolism, Cerebral hemorrhage, Hemorrhagic stroke, Intracranial hemorrhage, recovery period, malnutrition, nutritional insufficiency, Nutritional deficiency, Nutritional disorder, nutritional imbalance, Nutritional risk, Malnutrition risk, Nutrition-related risk, nutrition, nutrition, nutrition risk, influence factor, Influencing factors, Risk factor, Contributing factors, Risk prediction, Risk assessment, and Prognostic prediction—were used to search Chinese databases such as CNKI (China National Knowledge Infrastructure), Wanfang, VIP, and SinoMed (China Biomedical Literature Database) and English databases such as PubMed, Web of Science, Embase, and Cochrane Library ^[9–10]. The search terms were refined through multiple pre-tests before being applied in the databases, either as subject terms or keywords in titles/abstracts. The retrieval period spanned from the inception of each database to March 30, 2022.

The retrieved literature was reviewed and analyzed in terms of abstracts and full-text content to identify warning factors for malnutrition risk in stroke patients during the recovery period. Considering the applicability and feasibility of these factors in this patient population, nursing experts in neurorehabilitation were invited to supplement and refine the influencing factors. This process led to the initial drafting of the “Warning Factors for Malnutrition Risk Assessment Scale Prototype for Stroke Patients in the Recovery Period”, which includes three dimensions and 28 items.

2.3. Preliminary drafting of the assessment scale (initial version)

The research team referred to the Nutrition Risk Screening 2002 (NRS 2002) as a benchmark, statistically analyzing and organizing the retrieved literature to identify risk factors for malnutrition. The applicability of these factors in stroke patients during the recovery period was discussed, and neurorehabilitation medical and nursing experts were invited to further refine the influencing factors. Expert Selection Criteria: (1) ≥ 10 years of experience in neurorehabilitation medicine/nursing; (2) Bachelor’s degree or higher; (3) Intermediate or senior professional title; (4) Familiarity with the study content and voluntary participation. A total of six experts were invited, who adjusted and optimized the assessment tool items.

2.4. Development of the expert Delphi questionnaire

The research team developed the expert Delphi questionnaire through group discussions. The first round of expert consultation was semi-open-ended and comprised three sections. The first section was a cover letter to experts, which included the research background, objectives, instructions for completing the questionnaire, specific filling requirements, and contact information. The second section was the content evaluation form for the Warning Factors of Malnutrition Risk in Stroke Patients in the recovery phase during the Recovery Period, containing the preliminary draft items of the assessment scale, importance ratings for each item and dimension, relevance ratings, and a comments/recommendations column. Importance was assessed using a 5-point Likert scale (5 = Very important, 4 = Important, 3 = Moderately important, 2 = Slightly important, 1 = Not important at all), while relevance was evaluated using a 4-point Likert scale (4 = Highly relevant, 3 = Relevant, 2 = Slightly relevant, 1 = Not relevant at all). Following each dimension and item evaluation, comment and modification sections were included to allow experts to suggest revisions or additional items. The third section collected basic expert information and their evaluation rationale, including demographic details (gender, age, education level, professional title, and work experience) as well as the experts’ judgment basis (Ca) and familiarity level (Cs). The judgment basis covered four aspects—theoretical analysis, work

experience, literature references, and personal intuition—each rated by impact level (high, medium, or low), while familiarity was classified into five levels: very familiar, quite familiar, moderately familiar, slightly familiar, and not familiar at all.

2.5. Selection of experts

A total of 21–25 experts were selected from a tertiary Grade A hospital in Shiyan City. Inclusion criteria for experts: (1) ≥ 10 years of experience in stroke rehabilitation diagnosis and treatment, nutrition, rehabilitation nursing, or nursing management; (2) Bachelor's degree or higher; (3) Intermediate or senior professional title; (4) Familiarity with the assessment items and certain research capabilities; (5) Voluntary participation and ability to complete the expert consultation within the study timeframe. These carefully selected experts ensured high-quality, evidence-based input for refining the assessment scale.

2.6. Implementation of expert Delphi consultation

From 1st April 2022 to 1st June 2022, two rounds of expert Delphi consultations were conducted through WeChat, face-to-face meetings, and email. The item screening and expert opinion adoption criteria were as follows: items were retained only if they simultaneously met all three conditions — a mean importance and relevance score > 3.5 , a coefficient of variation (CV, Content Validity) < 0.25 , and a full-score rate (K) ≥ 0.2 ^[11]. After collecting the first-round questionnaires, key metrics, including expert response rate (positive coefficient), authority coefficient, importance and relevance scores for each risk factor, CV values, and K values, were calculated. Based on the consolidated expert feedback and statistical analysis, the assessment scale content was revised according to the established screening criteria. The research team then discussed the expert opinions to determine whether to accept proposed modifications and delete items with weak thematic relevance, resulting in the formulation of the second-round Delphi questionnaire. The second round was conducted two weeks later and included: (1) feedback on the first-round results, (2) importance and relevance ratings for risk warning factors in the second round, (3) expert demographic information, and (4) expert self-evaluation. The consultation results were systematically analyzed and, in conjunction with the screening criteria and expert recommendations, the risk warning factor assessment table was further refined to produce the final version of the evaluation scale.

2.7. Statistical indicators and scoring criteria

The statistical indicators primarily included the experts' positive coefficient, authority coefficient, and the degree of coordination among expert opinions. The positive coefficient reflected the experts' engagement with the research, as indicated by the response rate of the consultation questionnaires and the number of experts providing feedback, with a response rate exceeding 70% considered indicative of high expert enthusiasm. The authority coefficient (Cr) was determined by both the experts' judgment basis (Ca) and their familiarity level (Cs), calculated as $Cr = (Ca + Cs) / 2$; generally, a Cr value greater than 0.70 was regarded as indicating high reliability. The degree of coordination among expert opinions was expressed using Kendall's coordination coefficient (W), which ranged from 0 to 1, with values closer to 1 signifying higher consistency among expert opinions. The coefficient of variation (CV), calculated as the standard deviation divided by the mean ($CV = \text{standard deviation} / \text{mean}$), was used to assess the uniformity of expert opinions, where a smaller CV indicated greater consensus among experts. For the consultation questionnaire, the importance of

items was rated using a 5-point Likert scale (1–5), ranging from “Strongly disagree” (1) to “Strongly agree” (5), while relevance was assessed using a 4-point Likert scale (1–4), ranging from “Very irrelevant” (1) to “Highly relevant” (4). The familiarity level (Cs) was categorized as “Very familiar” (1.0), “Familiar” (0.8), “Moderately familiar” (0.6), “Not very familiar” (0.4), and “Not familiar at all” (0.2). The judgment basis was scored according to the degree of influence (large, medium, small), with practical experience assigned values of 0.5, 0.4, and 0.3; theoretical analysis assigned 0.3, 0.2, and 0.1; knowledge of domestic and international peers assigned 0.1, 0.1, and 0.1; and intuition also assigned 0.1, 0.1, and 0.1 for large, medium, and small influences, respectively.

2.8. Quality control

Data management was conducted using Excel 2013 to record experts’ ratings and modification suggestions for each scale item, with all entries double-checked, numbered, and entered by two independent researchers. To ensure the quality of the study: (1) All consulted experts were senior professionals with a strong interest in the research topic and capable of providing comprehensive perspectives; (2) The first-round questionnaire was developed based on literature review and preliminary clinical surveys, and offered in three formats (Word document, Wenjuanxing QR code, and paper version) for expert convenience; (3) Questionnaires were distributed via private WeChat messages using personalized and cordial language, with regular follow-ups to enhance response quality; (4) After collection, Wenjuanxing responses were directly exported to Excel, while Word-format questionnaires were independently entered by two researchers and cross-verified; (5) Any disputed indicators were discussed by the research team, with additional explanations sought from relevant experts when necessary.

2.9. Statistical methods

Statistical analyses were performed using Excel 2013 and SPSS 26.0 software. For quantitative data, normally distributed variables were expressed as mean \pm standard deviation (SD) ($\bar{x} \pm s$), and intergroup comparisons were conducted using *t*-tests. Categorical data were presented as frequency and percentage (%), with intergroup comparisons performed using chi-square tests. The positive coefficient of experts was indicated by the effective questionnaire recovery rate, calculated as (number of valid returned questionnaires/number of consulted experts) \times 100%. The authority coefficient (Cr) of experts was derived from the judgment basis coefficient (Ca) and the familiarity coefficient (Cs) regarding the survey content, where a higher Cr value indicated greater expert authority^[12]. The degree of consensus among expert opinions was evaluated using the coefficient of variation (CV) and Kendall’s W coefficient, where a smaller CV and a larger Kendall’s W value indicated better consistency among experts^[13]. Statistical significance was set at $P < 0.05$.

3. Results

3.1. General information on the experts

A total of 24 experts were ultimately included, comprising 6 males and 18 females, with ages ranging from 36 to 55 years (mean \pm SD: 44.83 ± 5.61 years) and professional experience in their respective fields spanning 11 to 31 years (mean \pm SD: 20.33 ± 6.74 years). The detailed demographic characteristics are presented in **Table 1**.

Table 1. Basic Information of the Consulted Experts (*n*=24)

Item	No.	Percentage (%)
Gender		
male	6	25.00
female	18	75.00
Age (years)		
31~40	8	33.33
41~50	12	50.00
≥51	4	16.67
Education level		
Bachelor's degree	14	58.33
Master's degree	10	41.67
Professional title		
Intermediate title	8	33.33
Associate senior title	12	50.00
Senior title	4	16.67
Work experience (years)		
11~20	9	37.50
21~30	14	58.33
≥31	1	4.17
Field of expertise		
Clinical rehabilitation nursing	10	41.67
Nursing teaching and research	1	4.17
Nursing management	4	16.67
Clinical medicine	5	20.83
Clinical nutrition	5	20.83

3.2. Expert responsiveness

In the first round of Delphi consultation, 25 questionnaires were distributed with 24 returned, yielding a recovery rate of 96%. The second round distributed 24 questionnaires, with all 24 returned, achieving a 100% recovery rate. Across both rounds, experts provided importance and relevance evaluations for all items, demonstrating a 100% response rate. The modification rates of expert feedback were 62.50% in the first round and 16.67% in the second round, indicating high levels of expert engagement.

3.3. Expert authority

For the two Delphi rounds, the judgment basis coefficients (*Ca*) were 0.926 and 0.933, familiarity coefficients (*Cs*) were 0.800 and 0.808, and authority coefficients (*Cr*) were 0.863 and 0.871, respectively. These values confirm high expert authority, ensuring reliable consultation outcomes.

3.4. Degree of expert consensus and coordination

The content validity of the assessment scale demonstrated strong reliability, with item-level content validity indices (I-CVIs) ranging from 0.875 to 1.000 and a scale-level content validity index (S-CVI) of 0.977. In the first round of expert consultation, dimension importance scores averaged between 4.000 and 4.250 (*CV* =

0.191–0.211), while item importance scores ranged from 3.667 to 4.917 (CV = 0.056–0.399), yielding a final importance score of 4.322 (CV = 0.182) with full-score rates of 0.21–0.92. For relevance, dimension scores averaged 3.542–3.625 (CV = 0.134–0.163) and item scores ranged from 3.375 to 3.398 (CV = 0.050–0.279), resulting in a final relevance score of 3.650 (CV = 0.148) with full-score rates of 0.50–0.96.

The second round showed improved consistency, with dimension importance scores of 4.125–4.458 (CV = 0.171–0.202), item importance scores of 3.833–4.875 (CV = 0.068–0.246), and a final importance score of 4.379 (CV = 0.174) with full-score rates of 0.29–0.92. Relevance scores were similarly refined, with dimension averages of 3.583–3.708 (CV = 0.123–0.137), item averages of 3.542–3.958 (CV = 0.050–0.199), and a final relevance score of 3.717 (CV = 0.126) with full-score rates of 0.54–0.96.

Statistical analysis revealed significant expert agreement, with Kendall's W coefficients for importance at 0.192 ($P < 0.001$) in the first round and 0.154 ($P < 0.001$) in the second round, while relevance scores showed Kendall's W values of 0.071 ($P < 0.05$) and 0.061 ($P < 0.05$), respectively. These findings confirm a high degree of consensus among expert evaluations.

3.5. Item modification results

Following discussions among the research team, additional items were incorporated into the assessment scale, including “number of children” in the basic information section, “NIHSS score”, “primary disease diagnosis”, “feeding method”, “types of medications taken”, “types of medications for digestive symptoms”, “dietary structure and preferences”, “ICF function”, and “standing/sitting balance” in the disease-related information section, as well as “liver and kidney function”, “prealbumin level”, and “hemoglobin level” in the laboratory indicators section. The final draft consisted of 3 dimensions and 36 items, comprising 10 items in Dimension 1, 21 in Dimension 2, and 5 in Dimension 3.

After the first round of expert consultation, the responses were analyzed, and modifications were made based on predefined item selection criteria through group discussions. Specifically, 3 items were revised, and 5 were added:

Newly Added Items: “degree of weight loss”, “mRS score”, “gastrointestinal function status”, and “dietary survey.”

Deleted Items: “estimated height and weight”, “disease stage”, and “APACHE II score.”

Modified Items: The item “height and weight” was changed to “BMI”, and “primary disease diagnosis” was revised to “number of disease diagnoses and their respective primary diagnoses.”

The updated draft then included 3 dimensions and 37 items, with 10 items in Dimension 1, 22 in Dimension 2, and 5 in Dimension 3.

Subsequent to the second round of expert consultation, further refinements were made based on the responses and item selection criteria. Specifically, 2 items were modified (“health insurance payment type” was expanded to include “commercial insurance”, and “history of previous surgeries” was revised to “history of previous gastrointestinal surgeries”), and 1 new item (“residence type”) was added.

The final version of the assessment scale comprised 3 dimensions and 38 items, structured as 11 items in Dimension 1, 22 in Dimension 2, and 5 in Dimension 3 (**Table 2**).

Table 2. Results of the second-round expert Delphi consultation

Serial number	Importance				Relevance				
	Mean	Standard deviation	CV	full-score rate	Mean	Standard deviation	CV	full-score rate	
A Basic Information	4.13	0.83	0.20	0.42	3.63	0.48	0.13	0.63	reserve
B Disease-Related Information	4.25	0.83	0.20	0.50	3.75	0.43	0.12	0.75	reserve
C Laboratory indicators	4.46	0.76	0.17	0.63	3.75	0.43	0.12	0.75	reserve
A1 Gender	4.04	0.89	0.22	0.38	3.63	0.48	0.13	0.63	reserve
A2 Age	4.04	0.89	0.22	0.38	3.63	0.48	0.13	0.63	reserve
A3 Education Level	3.88	0.83	0.21	0.29	3.58	0.57	0.16	0.63	reserve
A4 Employment Status	3.92	0.95	0.24	0.38	3.71	0.54	0.15	0.75	reserve
A5 Caregiving Type	4.17	0.99	0.24	0.46	3.75	0.43	0.12	0.75	reserve
A6 Monthly Family Income	3.83	0.94	0.25	0.29	3.54	0.64	0.18	0.63	reserve
A7 Type of Medical Insurance	4.13	0.88	0.21	0.42	3.58	0.64	0.18	0.67	reserve
A8 Marital Status	4.33	0.75	0.17	0.50	3.75	0.52	0.14	0.79	reserve
A9 Number of Children	4.17	0.80	0.19	0.42	3.54	0.71	0.20	0.67	reserve
A10 Smoking History	4.13	0.97	0.24	0.46	3.58	0.64	0.18	0.67	reserve
A11 Alcohol Consumption History	3.92	0.91	0.23	0.33	3.96	0.20	0.05	0.96	reserve
B1 Admission Method	4.25	0.78	0.18	0.46	3.54	0.50	0.14	0.54	reserve
B2 BMI	4.71	0.54	0.11	0.75	3.83	0.37	0.10	0.83	reserve
B3 Weight Loss	4.54	0.71	0.16	0.67	3.79	0.41	0.11	0.79	reserve
B4 Number of Diagnosed Diseases	4.54	0.71	0.16	0.67	3.75	0.43	0.12	0.75	reserve
B5 Onset Time	4.46	0.71	0.16	0.58	3.71	0.45	0.12	0.71	reserve
B6 First-Ever Stroke (Yes/No)	4.08	1.00	0.24	0.46	3.92	0.28	0.07	0.92	reserve
B7 Comorbidities	4.88	0.33	0.07	0.88	3.96	0.20	0.05	0.96	reserve
B8 Gastrointestinal Medications	4.63	0.63	0.14	0.71	3.71	0.45	0.12	0.71	reserve
B9 Number of Medication Types	4.17	0.75	0.18	0.38	3.71	0.45	0.12	0.71	reserve
B10 Activities of Daily Living (ADL) Score	4.50	0.76	0.17	0.67	3.63	0.63	0.17	0.71	reserve
B11 mRS score (Modified Rankin Scale score)	4.54	0.64	0.14	0.63	3.58	0.57	0.16	0.63	reserve
B12 Dysphagia (Swallowing disorder)	4.83	0.37	0.08	0.83	3.58	0.49	0.14	0.58	reserve
B13 Gastrointestinal function assessment	4.58	0.64	0.14	0.67	3.79	0.41	0.11	0.79	reserve
B14 Psychological depression status	4.38	0.63	0.14	0.46	3.58	0.70	0.20	0.71	reserve
B15 NIHSS score (National Institutes of Health Stroke Scale score)	4.46	0.91	0.20	0.67	3.79	0.50	0.13	0.83	reserve
B16 ICF function (International Classification of Functioning, Disability and Health function)	4.33	0.90	0.21	0.58	3.58	0.49	0.14	0.58	reserve
B17 Feeding method	4.79	0.50	0.10	0.83	3.83	0.37	0.10	0.83	reserve
B18 Dietary structure and preferences	4.21	0.87	0.21	0.46	3.83	0.37	0.10	0.83	reserve
B19 Past medical history	4.42	0.81	0.18	0.58	3.83	0.37	0.10	0.83	reserve

Serial number	Importance				Relevance				
	Mean	Standard deviation	CV	full-score rate	Mean	Standard deviation	CV	full-score rate	
B20 History of previous gastrointestinal surgery	4.21	0.96	0.23	0.46	3.67	0.47	0.13	0.67	reserve
B21 Timely treatment during the acute phase	4.38	0.75	0.17	0.54	3.67	0.47	0.13	0.67	reserve
B22 Dietary survey	4.54	0.64	0.14	0.63	3.75	0.43	0.12	0.75	reserve
C1 Hemoglobin level	4.88	0.44	0.09	0.92	3.83	0.37	0.10	0.83	reserve
C2 Electrolyte level	4.54	0.64	0.14	0.63	3.79	0.41	0.11	0.79	reserve
C3 Albumin level	4.75	0.60	0.13	0.83	3.88	0.33	0.09	0.88	reserve
C3 Prealbumin level	4.79	0.58	0.12	0.88	3.83	0.37	0.10	0.83	reserve
C4 Liver function	4.29	0.89	0.21	0.58	3.58	0.49	0.14	0.58	reserve
C5 Renal function	4.58	0.70	0.15	0.71	3.75	0.43	0.12	0.75	reserve

4. Discussion

4.1. The nutritional risk assessment scale for stroke patients in the recovery phase demonstrates good scientific validity and reliability

Currently, the assessment of nutritional risk in stroke patients during the recovery phase primarily relies on generalized (non-specific) scales, while specialized scales are still lacking ^[14]. In this study, based on the modified Delphi method, the authors provided structured questionnaires—developed through literature review and expert group discussions—to the consulting experts during the first round of consultation. Compared with the traditional Delphi method, the modified Delphi method concludes when consensus on the discussed topic is reached, making it more convenient for experts to make inferences and judgments within a short time ^[15]. Additionally, feedback on expert opinions was provided after the first round of consultation, which helped improve the accuracy and efficiency of the research.

In the selection of experts, all consulting experts had over 10 years of experience in relevant fields, with extensive clinical, nursing, and management expertise. Among them, 16 experts held associate senior or higher professional titles, and 10 experts had master's degrees.

The response rates for the two rounds of expert consultation questionnaires were 96% and 100%, respectively, and all experts evaluated the importance and relevance of the items, with a response rate >70%, indicating high enthusiasm among the experts ^[16]. The modification rates of expert opinions in the two rounds were 62.50% and 16.67%, respectively, demonstrating high engagement among the experts. The Cronbach's alpha (Cr) values for the two rounds of expert consultation were 0.863 and 0.871, both greater than 0.7, indicating high expert authority and reliable consultation results ^[17].

The Kendall's W coefficients for importance in the two rounds were 0.192 and 0.154 (both $P < 0.001$), while those for relevance were 0.063 and 0.067 (both $P < 0.05$), suggesting a high degree of consistency in expert evaluations of the indicators ^[18].

4.2. The nutritional risk assessment scale for stroke patients in the recovery phase demonstrates strong targeted applicability

Stroke patients in the recovery phase often experience dysphagia, cognitive impairment, and depression,

all of which contribute to an increased risk of malnutrition ^[6, 19–21]. Additionally, certain medications may exacerbate gastrointestinal burden, leading to impaired nutrient absorption ^[22]. Moreover, laboratory indicators such as albumin and prealbumin reflect the patient's nutritional risk to some extent ^[23–24]. In this study, through a literature review, the authors analyzed and summarized the key risk factors for malnutrition in stroke patients during the recovery phase ^[11, 25]. By employing the Modified Delphi Method for expert consultation, the authors developed a targeted nutritional risk assessment scale specifically for stroke patients in the recovery phase, enhancing its applicability and relevance to this patient population.

4.3. The nutritional risk assessment scale for stroke patients in the recovery phase demonstrates good practicality

Currently, for stroke patients in the recovery phase, clinically available tools for assessing malnutrition risk include the Nutritional Risk Screening 2002 (NRS2002) and the Malnutrition Universal Screening Tool (MUST) ^[25–26]. However, these tools have limited efficacy in identifying high-risk populations with malnutrition risk among stroke patients in the recovery phase. The nutritional risk assessment scale for stroke patients in the recovery phase developed in this study integrates demographic data, disease-related information, and laboratory indicators of patients, providing a reference for screening high-risk stroke patients with malnutrition.

5. Summary

This study developed a nutritional risk assessment scale for stroke patients in the recovery phase through a modified Delphi approach, integrating literature review and two rounds of expert consultation. And the final scale comprises 3 dimensions and 38 items. The development methodology demonstrated strong scientific validity and reliability, while the derived items exhibited notable targeting and practicality. This scale provides practical guidance for clinical practice and serves as a reference for accurately and efficiently identifying high-risk stroke patients with malnutrition during the recovery phase.

6. Limitations and future directions

The limitation is that all participating experts were from a single hospital, which may introduce potential biases in the findings. Future work will focus on applying the developed scale, including integrating it into software systems to enable automated calculation of patients' malnutrition risk scores, in order to validate its feasibility and practical effectiveness. Efforts will also be made to develop a risk prediction model.

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Research on the Current Situation and Improvement Methods of First-Aid Skill Practical Teaching for Higher Vocational Nursing

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Abstract: First aid skills are a major part of the professional competence of high vocational nursing talent. The quality of practical teaching directly relates to how many people who will be working with sick people can fix someone else's problems and save them. Now, with higher vocational nursing first aid practice teaching still has some shortcomings with what is covered in the courses, who is doing the teaching, and having all the necessary tools and resources available for students, as well as an evaluation of students' and teachers' performance, that kind of thing would be holding back raising these students' working abilities. Based on a thorough investigation into current teaching, the study identifies problem situations and reasons within, offering tangible solutions concerning curriculum organization changes and innovative teaching techniques, along with improved standards for evaluations. And support mechanisms, like institutional guarantee, medical education cooperation, resource investment, and so on, are also discussed to offer more ideas about changing first aider practical training for university nursing.

Keywords: Higher vocational nursing; First aid skills; Practical teaching; Teaching reform; Medical-educational collaboration

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1. Introduction

Nursing personnel need to acquire skills to save lives. The main place for training grassroots nursing personnel is colleges. Therefore, there is an obvious requirement for the necessity of teaching that practice in nursing programmes at colleges. In this complex world where people's health is affected, and all these things that people will do to be healthy, there is even more pressure put on nurses who will help out those who were hurt and people with injuries. But now, some first-aid skills practical teaching in present high professional colleges is very much lacking fresh ideas for instruction and training facilities for students who are eager to be ready and fit when they leave and start doing actual clinical work as soon as they can. Under such

circumstances, how to build up a scientific and good first-aid practical teaching system under scarce teaching resources is becoming an important problem that needs to be solved right away in higher vocational nursing. This study looks at the present state of first aid skills practical teaching in higher vocational nursing, figures out the hidden problems and why they are happening, tries out some ideas about fixing things, and provides some clues about what could possibly get some improvements in terms of teaching, just in case someone else wants to try and change some stuff around ^[1].

2. Current situation of first aid skills practical teaching

2.1. Curriculum setting

The current first aid courses in the college for nurse course have been carried out through “theoretical plus individual skills” with it being mostly found in the basics of nursing and critical care nursing, and only having limited practical sessions that were on their own. Class hour allocation indicates an obvious priority given to theory over practice, resulting in minimal time for practical application by students. The course content covers fundamental first aid techniques such as CPR, bleeding control and bandaging, airway management, and fracture fixation. It does not place significant emphasis on the broader capabilities required for comprehensive disaster rescue or pre-hospital emergency response. There is no unified and standardized curriculum guideline to be followed by all colleges. Hence, different choices have been made in terms of what has been chosen as a teaching point, as well as how these points move along when it comes to increasing their level of difficulty, thus creating differing skill sets after graduation for those who complete this program.

2.2. Faculty Structure

The higher vocational first aid course faculty comprises mainly full-time teachers and part-time clinical instructors. Most of them were from a medical or nursing background; they were not very connected to real-world clinics for long periods, which means not have much practical skill in treating people. Some teachers have never learned or have not updated quickly regarding the most current first-aid rules and hospital operation standards. The part-timers have lots of experience, but they do not spend much time as teachers, so it is tough for them to take an ongoing and in-depth part in the classroom. Furthermore, the proportion of “dual qualification” (teaching and profession certification), teachers among all teachers on the first-aid subject is small. Faculty structure has generational differences and structural title differences between junior and senior faculty; junior has no practical experience, while senior faculty do not learn as quickly. This structural conflict affects how good teachers can be at their jobs and whether what their teaching lines up well with being doctors who deal with sick people right now.

2.3. Training environment and equipment conditions

Most higher vocational colleges have set up nursing training centers that contain basic first aid training tools such as CPR mannequins, bag-valve masks, spine boards, and stretchers. But there is not enough equipment for all the students, so each student does not get much time to practice. High-end intelligent training equipment, such as manikins with real-time feedback functions and a virtual simulation first aid training system, is uncommon, limiting the depth of scenario-based simulation teaching development. Some colleges have inflexible training room management systems, restricted open access periods beyond class times, and

late restocking of instructional supplies, impacting the general efficiency of hands-on instruction and ongoing enhancement of students' skills ^[2].

3. Problems encountered during teaching

3.1. Teaching content does not match the clinical practice

The existing first aid practical teaching contents focus on textbook knowledge and standard operating procedures, which fail to simulate the complexity and urgency of real clinical situations. Classroom learned operations steps are hard to be directly used in the changing environment of pre-hospital emergency care. Teaching case updates are slow, not adding new ideas and tools from the pre-hospital world fast enough, such as group CPR and using new bandages for injuries. Some operation procedures still use the old version rules, different from the present clinical standards, making students have to adapt again during their internship. The efficiency of turning teaching resources into something that can be applied in a clinical setting needs to improve.

3.2. Teaching in the same manner as before

First aid skill training teaching is still mainly based on the teacher's demonstration, and the students' practice by imitation. Using scenarios and simulations and then high fidelity cases is too small and leaves the kids in the room being a little bit too passively receiving it all when they could use some actual hands-on judgment and deciding how it gets made. Interactive teaching method groups perform collaborative drills and role play, so that the teaching is not merely just a routine, thus ensuring the students are taught the ability to prepare psychologically for emergencies, as well as their ability to cooperate. Because of teaching timetables and equipment, students mostly do mechanical repetitive practice, operational steps, and do not get chances to respond together, with lots of stress. And that problem with how they teach it makes those students less able to think clinically, less good at deciding stuff in emergencies.

3.3. Incomplete assessment and evaluation system

Current first aid skill assessments mainly adopt individual operation scoring systems, evaluating each step according to a pre-set checklist, emphasizing operational standards over clinical judgment, adaptability, and humanistic care. Summative assessment dominates, with formative evaluation accounting for a small proportion, unable to adequately reflect students' progress during routine exercises. Assessment scenario is different from the actual emergency situation, so it is hard to know how well students can handle everything at once when there is stress. Evaluation dimensions are rather flat, not a good way to check if someone can talk and work together, decide what is going on, or pick what to do first. This stops giving all-around feedback about how well teaching works and how to make it better.

4. Analysis of causes of problems

4.1. Lack of institutions stressing practical teaching

Some higher vocational schools still follow old ideas about first things first. When it comes to making their nursing programs, they look at actual lessons taught in real life as something that just goes with classes where students learn about theories. This results in not really having much overall planning on top of first

aid practical training. Resources tend to go toward theory and research; there is less money for practical teaching. The practical teaching management system is often incomplete. Teachers' practice ability lacks strict regulations and appraisals, so there is little motivation to make changes to practical instruction. This cognitive flaw and administration gap basically keep the improvement of the quality of the first help practical education constant ^[3].

4.2. The teachers do not have enough clinical practice experience

The vast majority of higher vocational nursing teachers get into their teaching roles right out of graduation without much or any kind of actual hands-on experience with clinics. No one has true knowledge about how these real-life workflows operate under that immense and intense pressure from the front lines of the emergency room, so they cannot really faithfully recreate the actual situation that exists inside the hospital for teaching purposes. Opportunities for in-service clinical refreshment training are few. Knowledge update mainly through self-study of literature and short-term training, resulting in poor knowledge of advanced techniques of first aid and a change in clinical management. Institutions do not provide a channel or incentive for the continuous improvement of a teacher's ability to perform clinical duties. There is a difference between what one does and the requirements for the job. There is a chasm there for those who can and those who must have something to do about it; it is a major reason why one sees this practical instruction of first aid lacking any substance, just going its own way all alone.

4.3. Outdated teaching resources and slow updates

Emergency medical technology keeps advancing, yet the updating speed of teaching apparatus in higher professional institutes frequently gets held back by procurement cycles and budget approval procedures, and ends up with equipment that is outdated compared to what is used clinically. Textbooks and teaching resources do not keep up with the current time. When they make changes to the clinical guideline, some content and tech standards have passed today's industry. Information-based education resources, which educators can use to make simulations, have not got any kind of use just yet. High-quality first aid teaching case libraries and standardized patient training systems have not been fully developed, depriving it from having sufficient material and technical support for their teaching reform. This lack of capacity within the teaching resource means that there will be no room for anything to be changed about teaching.

5. Ways to make it more practical in the classroom

5.1. Rebuilding modular teaching content

According to the competency requirements of the position of clinical first aider, structure the contents of the teaching of first aid skills into modules, including basic life support, trauma first aid techniques, common emergencies treatment, and disaster scene handling. Each module should build upon a progressive set of competency goals, going from a single skill being standardized up through simulated scenarios, all the way to managing it as a team, creating a spiral of progression. Update on time so that teaching contents follow the newest global CPR norms and medical rescue criteria, introducing new techs as the field hospital's tourniquet use, and fast resuscitation team work. Improve the job-relevance and future-sightedness of what gets taught technically in order for students studying right now to understand these same present clinical first-aid skills they will be working on once.

5.2. Encouraging blended teaching methods

Use online teaching platforms as a means before the lesson so that there is more room in the class for high-fidelity scenario training and detailed instruction. Vigorously promote case-based scenario simulation teaching by creating standard first aid scenarios taken from real-life clinic events. Let students do the whole thing, from injury checking and first-aid treatment, and choice to transport via playing roles and teamwork. Provide intelligent training machines with immediate feedback, such as how deep the compression was and what speed they used, to assist pupils with making the necessary corrections. Raise easy operating exercise into exact, feedback-boosted teaching, greatly improving how good a teacher can be at it ^[4].

5.3. Creating a diverse measure standard

Build up the indicator framework with those 4 operation techniques and clinical thought processes, and work together, also showing sympathy. Use both standardized score evaluations and qualitative ones to thoroughly evaluate student achievement results. Increase its weight, add it as a regular practice quality, and simulate performances and a reflective report. When setting up assessment scenarios, make them more like real clinical situations where distractions, time pressures, etc., can be put on students to see how well they do in an emergency situation. With the reform of the evaluation system, make people pay attention to teaching rather than being standardized operation only, and develop comprehensive competence instead.

6. Supporting mechanisms for teaching improvement

6.1. Creating real training administration systems

Institutionally commit to making actual teaching the principal part of the nursing personnel building. Issue special management regulations on first-aid practical training, with content including basic education level, the necessary number of practice hours, practice equipment setup, and instructor qualification requirements. To create an institutionally normalizing quality assessment and feedback mechanism regarding the practical aspects, carry out routine evaluations and inspections regularly, and integrate the outcome into professionals' and teachers' appraisals. Ensure a guarantee for practical instruction in emergencies in organizations. It must have an organizational form that is strict enough, and then do the remodeling of the process management so that it will take some effort. It must be more than a pretense.

6.2. Medical-educational collaboration platform deepens

Normalize the college's partnership with the affiliated hospitals/partnering medical facility. Allow regular inclusion of clinical nursing on-campus first aid teaching, at which time have the part-time instructors be rotated to emergency departments and ICU departments so as to maintain clinical competency, and create faculty exchange that is both reciprocal and experientially shared. This is to ensure teaching using real case studies from real-world practices. Hold first aid competition as well as emergency drills together; change from the hospital to the school's teaching support ^[5]. Establish an interactive ecology of education and healthcare via medical-education cooperation in such a way that the students can get closer to real training scenarios through more realistic practices.

6.3. Increased investment in training base construction

Think rationally about how the training rooms can be zoned. Provide a sufficient quantity of basics, introduce

clever simulation teaching things as well as artificial imitation training systems, so it would be able to provide technological help on training for emergency services staff. Establish a special account mechanism for consumable goods for teaching to guarantee timely refilling of necessary nursing practice supplies, as well as regularly maintaining and updating other equipment. Increase the usage rate of the training room in open access. The training environment is closer to a hospital, which creates immersive first-aid scene simulations, making it so students can repeat the act of performing first aid and gain their composure under a very real atmosphere and thus have a firm base upon graduating into the workforce.

7. Conclusion

In order to enhance the first aid abilities practice teaching inside a higher vocational school nursing, this is an undertaking full of time-consuming investments which covers many different areas, such as updating teaching contents, improving methods of education, and setting up and improving a new evaluation system guarantee mechanism as well. After systematically reviewing and investigating the current state of affairs and the cause of problems, the author comes to believe it is possible for some kind of structure and systematic changes that emphasize the main parts of medical-educational collaboration and institution building that would cause change. Future, higher vocational colleges should carry out the improvement measures at stages depending on their own context, constantly promoting the conversion of the first-aid practical instruction from the sole skill teaching direction toward the improvement of comprehensive emergency response skills, and producing high-standard nursing personnel who have first aid ability to the primary healthcare system.

Disclosure statement

The author declares no conflict of interest.

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Exercise Intervention for Depression from the Perspective of Gut Microbiota Dysbiosis: A Review

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Abstract: Depression is a mental disorder with a complex pathogenesis. In recent years, the “gut-brain axis” theory has revealed the key role of gut microbiota dysbiosis in its development. Studies have shown that exercise can effectively improve gut microbiota dysbiosis and alleviate depressive symptoms. From the perspective of gut microbiota dysbiosis, this paper systematically explores the potential mechanisms of exercise in preventing and treating depression. The paper reviews how exercise intervenes in neurotransmitter pathways and HPA axis function through multiple dimensions, such as regulating microbial structure, inhibiting the proliferation of pro-inflammatory bacteria, and promoting the synthesis of short-chain fatty acids. Combined with the traditional Chinese medicine (TCM) theory of “Yu syndrome”, the article proposes an integrated prevention and treatment approach of “exercise—gut microbiota—brain function.” Finally, it looks forward to future research directions.

Keywords: Gut microbiota; Depression; Exercise therapy; Gut-brain axis; Yu syndrome

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1. Gut microbiota dysbiosis and depression

Gut microbiota plays an important role in regulating the function of the central nervous system. The mechanisms by which microbiota dysbiosis leads to depression mainly include the following aspects.

1.1. Decreased microbiota diversity

Gut microbiota diversity is an important indicator of intestinal health. There are significant differences in gut microbial diversity between patients with depression and healthy individuals. Kelly JR et al. confirmed through 16S RNA sequencing of fecal samples that depression is associated with reduced richness and diversity of the gut microbiota^[1]. Exercise can significantly increase gut microbiota diversity. A recent study by Clarke et al. showed that the gut microbiota of rugby players is more diverse compared to healthy non-

athlete professional men; the α -diversity of the microbiota of elite athletes is higher than that of the general population in the two control groups ^[2].

1.2. Proliferation of pro-inflammatory bacteria

Pro-inflammatory bacteria proliferate under stress. Lipopolysaccharide, a component of their cell walls, can activate immune responses, trigger low-grade inflammation in the intestines and even the whole body, thereby affecting the central nervous system and ultimately leading to depressive behaviors. Liu Lanxiang et al. found that the abundance of pro-inflammatory bacteria, such as Proteobacteria, in the feces of inactive people is increased, which is highly consistent with the microbial characteristics of patients with depression ^[3]. Regular exercise can reduce the relative abundance of pro-inflammatory bacteria. A systematic review by Mailing et al. pointed out that aerobic exercise can significantly reduce the relative abundance of Proteobacteria and Enterobacteriaceae, reduce LPS translocation, and thus improve the state of systemic low-grade inflammation ^[4].

1.3. Impaired synthesis of short-chain fatty acids (SCFAs)

Short-chain fatty acids (SCFAs) have anti-inflammatory, intestinal barrier-protecting, and neuroprotective effects. A sedentary lifestyle may lead to a significant decrease in the overall level of intestinal SCFAs, while regular exercise can promote the proliferation of butyrate-producing bacteria, thereby increasing SCFAs levels. The promoting effect of exercise on SCFAs has been directly verified by experimental studies. J M Allen et al. found that after transplanting the gut microbiota of exercise-trained mice to recipient mice, the ratio of propionic acid to butyric acid in the intestines of the recipient mice was significantly increased ^[5].

2. Connection between gut microbiota dysbiosis and pathological mechanism hypotheses of depression

2.1. Gut microbiota and monoamine neurotransmitter hypothesis

Monoamine neurotransmitters have significant biological activities in regulating mood, cognitive function, and stress response, and are closely related to the occurrence and development of depression. Liu Lanxiang et al. found that the expression levels of genes related to the monoamine neurotransmitter pathway in germ-free mice are significantly reduced, and depressive behaviors are increased ^[3]. After gut microbial re-colonization, depressive behaviors can be significantly improved.

Exercise can reshape the gut microbiota. Its metabolites, such as acetic acid (a type of SCFA), can cross the blood-brain barrier and regulate the balance of neurotransmitters such as dopamine. Some microbiota can directly synthesize neurotransmitters such as GABA; at the same time, SCFAs can also provide precursors for the synthesis of 5-HT by regulating pathways such as tryptophan metabolism, thereby systematically improving the function of monoamine neurotransmitters. This indicates that regulating the gut microbiota through exercise and its metabolites is an important link for exercise to exert antidepressant effects.

2.2. Gut microbiota and HPA axis dysregulation hypothesis

Stress activates the HPA axis, leading to increased levels of hormones such as cortisol. Long-term hyperactivity can damage nerve cells and produce depressive behaviors. Exercise can improve HPA axis function. Chen Xuemei et al. found that when the gut microbiota of rats that exercised was transplanted

into ASD rats, the activation of the HPA axis in the transplanted ASD rats was lower than that in the control group ^[6]. Thus, it can be initially concluded that exercise balances HPA axis activation by improving the gut microbiota, thereby regulating depression.

3. Treatment of depression from the perspective of exercise

Exercise therapy is an important treatment method for depression, including aerobic exercise such as jogging and swimming, strength training, and flexibility training. A large number of empirical studies have strongly shown that exercise therapy can improve the composition of gut microbiota. Therefore, this article believes that exercise can indirectly target depression to achieve therapeutic effects.

3.1. Aerobic exercise

A randomized controlled trial on adults with mild depression found that moderate-intensity running training (3 times a week for 12 weeks) significantly increased the relative abundance of *Akkermansia muciniphila* and *Faecalibacterium prausnitzii* in feces. Both types of bacteria are closely related to anti-inflammatory effects and enhanced intestinal barrier function ^[7]. In addition, the gut microbiota shaped by running itself has anti-inflammatory properties. Transplanting the microbiota of exercisers to germ-free mice can reduce the inflammation level of the latter.

3.2. Mind-body exercise

Mind-body exercises, such as meditation and Tai Chi, have been widely used in the auxiliary intervention of emotional disorders in recent years, and their potential to regulate gut microbiota has also attracted attention. Raman M et al. found that beta diversity showed significant changes in the microbial composition of meditators ($P=0.001$) ^[8]. At the same time, meditators had higher levels of branched-chain short-chain fatty acids (SCFAs). The above studies suggest that mind-body exercise may improve microbial structure, enhance SCFAs synthesis, and reduce neuroinflammation through bidirectional regulation of the “gut-brain axis”, thereby alleviating depressive symptoms.

4. Conclusion and prospect

The pathogenesis of depression involves interactions between multiple systems, and the “gut-brain axis” provides a new perspective for understanding its mechanism. Gut microbiota dysbiosis is involved in the occurrence of depression by affecting inflammation, neurotransmitters, the HPA axis, and synaptic plasticity.

As a holistic intervention, exercise can improve depressive symptoms through multiple pathways, such as reshaping gut microbiota structure, inhibiting pro-inflammatory bacteria, and promoting SCFAs synthesis. Integrating TCM “Yu syndrome” theory, this article proposes an integrated prevention and treatment approach of “exercise—gut microbiota—brain function.”

In the future, more in-depth research is needed to explore the optimal exercise intensity, duration, and type for regulating gut microbiota and exerting antidepressant effects; clarify the key microbial species and their metabolites involved in the antidepressant effect of exercise; and further verify the clinical application value of the “exercise—gut microbiota—brain function” intervention model, so as to provide more personalized and effective treatment options for patients with depression.

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Disclosure statement

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Current Status and Influencing Factors of Cardiovascular and Metabolic Comorbidities in Ischemic Stroke Patients

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Abstract: This study aims to explore the epidemiological characteristics, influencing factors, and specific impacts on clinical prognosis of cardiometabolic multimorbidity (CMC) in patients with ischemic stroke. By analyzing the clinical data of 864 hospitalized patients with ischemic stroke, the study found that CMC is highly prevalent in this population, with an overall prevalence of 68.29%, among which hypertension, dyslipidemia, and diabetes mellitus are the most common types of comorbidities. Multivariable Logistic regression analysis revealed that advanced age, smoking, high salt intake, and lower socioeconomic status are key risk factors for the occurrence of CMC. Regarding the impact on prognosis, this study confirmed that the CMC status significantly increases the risk of the first stroke occurrence, which grows exponentially with the number of metabolic abnormalities. Follow-up data showed that the one-year recurrence rate in the CMC group (15.68%) was significantly higher than that in the non-CMC group (9.24%). Furthermore, patients with CMC exhibited more severe neurological deficits during the acute phase and slower recovery of long-term activities of daily living. Based on these findings, the study proposes the construction of a full-chain management system ranging from primary prevention to intensive secondary prevention, emphasizing the central role of the Multidisciplinary Team (MDT) model in improving the prognosis of patients with complex multimorbidity. This study provides important evidence-based medical grounds for optimizing clinical management pathways and public health prevention strategies for stroke patients in China.

Keywords: Ischemic stroke; Cardiometabolic multimorbidity; Epidemiology; Influencing factors; Prognosis

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1. Introduction

Ischemic stroke is a serious disease in the world that can cause significant harm to human life due to a high incidence rate, severe disability, and death; at the same time, it also places an economic burden on society. According to recent statistics from the World Health Organization (WHO), about 30 million people globally are living with chronic stroke. The public health problem here in China is very serious. Chen Xiaorong and others have studied the features of stroke occurrence and death among people in China from 2015 to

2019. As shown in the results, ischaemic stroke is one of the many kinds of stroke, and its occurrence rate and prevalence have been rising steadily over time, posing a problem for the national health system ^[1]. At the same time, with the development of the social economy, changes in lifestyle, and the acceleration of population ageing, cardiovascular and metabolic risk factors have become increasingly common among the population, and thus, the phenomenon of comorbidities in cardiovascular and metabolic diseases is also occurring more frequently.

Cardiovascular-metabolic comorbidity (CMC) refers to the cluster of multiple diseases, such as hypertension, diabetes, dyslipidemia, obesity, and coronary heart disease, in the same person; it is no longer an occasional case but a widespread and complicated condition. The diseases are connected and can be promoted from one to the other through the same pathological process; for instance, insulin resistance, chronic inflammation, endothelial dysfunction, and oxidative stress often occur together in a vicious cycle. The incidence of CMC is relatively high in people with ischemic stroke. Before the onset of a stroke, many people show one or more metabolic abnormalities, and these abnormal states are considered the “soil” that promotes the development and progression of cerebral atherosclerosis. At present, the management system for stroke patients mainly focuses on the stroke event itself, and all-around care and coordinated treatment of related metabolic diseases have not been fully realised. Chen Yingying and others have studied the current situation of comorbidity among older people, noted that managing multiple comorbidities is difficult, and highlighted the deficiencies in the existing healthcare system’s ability to care for such patients; therefore, it provides a foundation for this paper ^[2]. Therefore, how to effectively determine, evaluate, and manage the CMC status of patients with ischaemic stroke has become an important problem that needs to be addressed scientifically and clinically in order to improve the level of stroke prevention and treatment and enhance long-term outcomes for patients.

2. Current status of cardiovascular and metabolic comorbidities in ischemic stroke patients

2.1. Overall occurrence of comorbidity

Cardiometabolic comorbidity exhibits a highly prevalent trend among patients with ischemic stroke. After analyzing the clinical data of 864 ischemic stroke patients included in this study, it was found that the number of patients with at least two cardiometabolic comorbidities (defined as any two or more of hypertension, diabetes, dyslipidemia, or coronary heart disease) reached 590, with an overall comorbidity rate as high as 68.29%. This data clearly indicates that more than two-thirds of ischemic stroke patients must face complex metabolic disorders while dealing with cerebrovascular disease itself, and the coexistence of multiple diseases is the norm rather than the exception for this patient population ^[1].

Among all patients, those who did not have or only had one type of cardiometabolic disease accounted for 31.71%. In the cohort of patients with comorbidity, the proportion of those with two comorbidities was the highest, accounting for 41.32% of the total sample ^[2]; while the proportion of patients with more complex conditions, having three or more comorbidities, also reached 26.97%. This phenomenon of disease clustering suggests that the pathophysiological basis of a considerable number of stroke patients is the result of long-term combined effects of multiple risk factors, which doubles the difficulty and challenge of clinical management. The findings of this study are consistent with the trends observed in multiple domestic and international research results. For example, Mulugeta et al. (2021) identified different metabolic subgroups in

a large-scale population study conducted in the UK Biobank and revealed the prevalence of cardiometabolic comorbidity ^[3]. Batista et al. (2022) also found a similar high comorbidity rate in a registry study of hypertensive patients in Brazil ^[4]. Han Ke et al. (2020) conducted a study on elderly patients with esophageal cancer, which similarly showed the widespread distribution of cardiometabolic diseases, indicating that comorbidity is a common issue faced by multiple elderly patients with chronic diseases ^[5]. These findings collectively highlight the urgency and necessity of integrating comorbidity management into the routine diagnosis and treatment pathways for specific diseases such as stroke.

2.2. Common types of cardiovascular and metabolic comorbidities

To gain a more detailed understanding of the comorbidity spectrum of patients with ischemic stroke, this study conducted separate statistics on the prevalence of several of the most common cardiometabolic diseases. These diseases are not only independent risk factors for stroke, but their interactions also further exacerbate the damage to the cerebrovascular system.

Hypertension is the most prevalent condition among the stroke population studied, with a significantly higher prevalence rate compared to other conditions. This is followed by dyslipidemia, diabetes, obesity, and coronary heart disease. This distribution pattern clearly outlines the core metabolic risk characteristics of stroke patients, namely multiple metabolic disorders primarily driven by abnormalities in blood pressure, lipids, and blood glucose.

2.2.1. Hypertension

Hypertension is the most important and common risk factor for ischemic stroke, with a prevalence rate of up to 76.27% in this study cohort. This proportion is basically consistent with the results of large-scale epidemiological surveys both domestically and internationally, once again confirming the central role of blood pressure management in stroke prevention and treatment. Long-term and sustained elevated blood pressure causes damage to the cerebrovascular system through multiple mechanisms. On the one hand, hypertension can directly cause hyaline degeneration and fibrinoid necrosis of cerebral arterioles, leading to reduced vascular elasticity and luminal stenosis, which is particularly prone to causing lacunar infarction. On the other hand, hypertension is a key initiator and accelerator of cerebral atherosclerosis. It damages vascular endothelial cells, promotes lipid deposition and plaque formation, and ultimately leads to stenosis or occlusion of large and medium-sized arteries by increasing the shear stress and mechanical stretch of the vascular wall. This study further found that the control status of hypertension is also not optimistic. Among patients who have been diagnosed and treated with antihypertensive therapy, only 34.72% have their blood pressure stably controlled below the target value (<140/90 mmHg). This means that most patients with hypertension are in a state of poor blood pressure control for a long time, continuously enduring the damage of hypertension to target organs. The research data also show that there is a significant positive correlation between the variability of systolic blood pressure at admission and the severity of stroke in patients (as assessed by the National Institutes of Health Stroke Scale, NIHSS), suggesting that unstable blood pressure may exacerbate ischemic damage to brain tissue in the acute phase.

2.2.2. Diabetes

Diabetes is another metabolic comorbidity closely related to ischemic stroke. In this study cohort, patients with diabetes or impaired glucose tolerance accounted for 31.83%. Wang Jiating et al. (2021) analyzed over

one million type 2 diabetes patients in Beijing and also revealed the epidemiological characteristics of their common comorbidities ^[6]. Among them, cerebrovascular disease was one of the important comorbidities, which corroborates the findings of this study. The damage of diabetes to the cerebrovascular system is multifaceted and systematic. Long-term hyperglycemia accelerates the progression of atherosclerosis through various pathways, including inducing vascular endothelial dysfunction, promoting the glycosylation and oxidation of low-density lipoprotein, activating platelets, and causing a chronic low-grade inflammatory state. In addition, the specific microvascular complications of diabetes also affect the brain, impairing the automatic regulation function of cerebral blood flow and making brain tissue more vulnerable to blood pressure fluctuations or decreased blood flow. The data from this study show that stroke.

2.2.3. Dyslipidemia

Dyslipidemia, particularly changes centered around elevated low-density lipoprotein cholesterol (LDL-C), is the cornerstone of atherosclerotic cardiovascular and cerebrovascular diseases. In the ischemic stroke patients studied, the overall prevalence of dyslipidemia reached 44.68%, making it the second most common comorbidity after hypertension. Among them, hypercholesterolemia and mixed hyperlipidemia, primarily characterized by elevated LDL-C, are the main manifestations. LDL-C, as the “bad cholesterol”, when its concentration in the blood is too high, is prone to penetrate the damaged vascular endothelium and enter the vascular wall. After undergoing oxidative modification, it is engulfed by macrophages to form foam cells, which is the initial step in the formation of atherosclerotic plaques. As the plaques continue to grow, they can lead to stenosis of cerebral arterial lumens; if the plaques rupture, they can rapidly form thrombi, completely blocking the blood vessels and triggering acute ischemic stroke. This study found that there is also a significant gap in lipid management among stroke patients. The average LDL-C level upon admission was 3.24 mmol/L, which is much higher than the control target recommended by current guidelines for extremely high-risk populations. More concerning is that only 28.4% of patients could strictly control LDL-C below the secondary prevention target value of 1.8 mmol/L. This indicates that despite the widespread use of statins, the lipid compliance rate in actual clinical practice remains low. A large number of stroke patients are still exposed to the significant residual risk posed by high LDL-C, which is undoubtedly one of the important causes of stroke recurrence.

3. Influencing factors of cardiovascular and metabolic comorbidities in ischemic stroke

3.1. Age factor

Age has a fundamental impact on the occurrence of cardiovascular metabolic comorbidities in ischemic stroke, mainly manifested in a series of physiological degenerative changes that occur in the body over time. As age increases, endothelial cells gradually experience functional decline, reduced elasticity of the vascular wall, and weakened arterial compliance. These structural and functional changes lead to a gradual decrease in the ability of blood vessels to regulate hemodynamic changes. Under normal circumstances, endothelial cells can secrete various active substances that regulate vascular tone, such as nitric oxide and prostacyclin, which play an important role in maintaining vasodilation and inhibiting platelet aggregation. As age increases, the ability of endothelial cells to produce nitric oxide gradually decreases, while oxidative stress response increases, leading to weakened vasodilation and increased risk of thrombosis. Under

long-term blood flow shock, the elastic fibers of the arterial wall gradually undergo degeneration, the content of collagen fibers relatively increases, the vascular wall gradually becomes harder, and the arterial compliance decreases. This change gradually increases systolic blood pressure and promotes the formation of hypertension. The metabolic regulatory system also undergoes changes during the aging process, with pancreatic beta cell function gradually declining, insulin secretion ability decreasing, and peripheral tissue sensitivity to insulin decreasing, thereby weakening blood glucose regulation ability. Lipid metabolism also changes during the aging process, and the liver's ability to regulate lipoprotein metabolism decreases, leading to a gradual increase in low-density lipoprotein levels. Aging is accompanied by an increase in chronic low-grade inflammatory response, which is believed to be closely related to the occurrence of various metabolic diseases. Long-term existence of inflammatory mediators will damage the vascular endothelium and promote the progression of atherosclerosis. With the continuous accumulation of various physiological changes, elderly individuals are more likely to suffer from metabolic diseases such as hypertension, diabetes, and dyslipidemia. When these diseases coexist in the same body, the probability of cardiovascular metabolic comorbidities increases significantly. The cerebrovascular system also undergoes structural changes during the aging process, with the walls of small arteries gradually thickening and becoming transparent, causing narrowing of the vascular lumen and reducing cerebral blood flow reserve capacity. The decline in cerebral microcirculation function makes brain tissue more sensitive to ischemia, and once there is a decrease in blood flow, it is easy to cause brain tissue damage. Age can also affect an individual's lifestyle, such as reduced physical activity and lower basal metabolic rate, which further promotes the formation of metabolic abnormalities. Multiple physiological and behavioral factors work together to make the elderly population an important high-risk group for cardiovascular metabolic comorbidities.

3.2. Gender factors

Gender differences have a significant impact on the occurrence of cardiovascular metabolic comorbidities, and their mechanisms involve multiple aspects such as differences in hormone levels, body fat distribution characteristics, and behavioral patterns. The probability of metabolic abnormalities occurring in men during early adulthood is relatively high, which is partly related to lifestyle factors such as higher smoking and alcohol consumption rates in men compared to women. Additionally, irregular eating habits and inadequate weight management are more common in the male population. Long-term smoking will damage vascular endothelial function and promote atherosclerosis, while excessive drinking will affect lipid metabolism and increase blood pressure. These behavioral factors together increase the probability of metabolic abnormalities in men. Sex hormone differences also play an important role in metabolic regulation. Estrogen has a protective effect on the cardiovascular system in women. This hormone can promote the release of nitric oxide from vascular endothelium and maintain vasodilation, while also helping to maintain favorable lipid structure, such as increasing high-density lipoprotein levels and reducing low-density lipoprotein levels. Estrogen also participates in regulating fat distribution, making fat more distributed in subcutaneous tissue rather than visceral areas. The accumulation of visceral fat is closely related to insulin resistance and inflammatory response, so the incidence of metabolic diseases in women is relatively low in the premenopausal stage. As women enter menopause, the level of estrogen in the body rapidly decreases. This hormonal change can lead to changes in the distribution pattern of body fat, a gradual increase in visceral fat proportion, and an upward trend in blood lipid and blood pressure levels. Postmenopausal women have a significantly increased probability of developing hypertension, dyslipidemia, and central obesity, which

gradually approaches or even exceeds the risk of cardiovascular metabolic comorbidities among men of the same age. Gender differences are also reflected in muscle mass and basal metabolic rate. Men usually have higher muscle content, which makes their basal metabolic rate relatively higher. However, if they lack exercise, they are prone to excessive energy intake and obesity. After menopause, women's muscle mass gradually decreases, and their basal metabolic rate decreases, which also increases the risk of weight gain. Social role differences may also affect metabolic health; for example, some women may lack sufficient exercise time under family and work pressure, while men may develop irregular eating habits under occupational pressure. These complex factors interact with each other, resulting in significant differences between genders in the formation of cardiovascular metabolic comorbidities.

3.3. Life behavior factors

Behavioral factors play a crucial role in the formation of cardiovascular metabolic comorbidities, which are modifiable risk factors and therefore of great significance in disease prevention strategies. Smoking behavior is considered an important risk factor for vascular damage. The various chemicals produced during tobacco combustion can directly damage endothelial cells, reduce vasodilation ability, and promote inflammatory reactions. Nicotine can also stimulate the sympathetic nervous system, accelerate heart rate, and increase blood pressure levels. Long-term effects can lead to changes in vascular structure. Oxidative substances in tobacco also increase the oxidation degree of low-density lipoprotein, thus accelerating the formation of atherosclerotic plaque. Dietary structure also plays an important role in metabolic health. A high salt diet will increase sodium ion retention in the body and lead to an increase in blood volume, making the blood pressure level rise continuously. Long-term high salt intake may also damage vascular endothelium and alter vascular smooth muscle function, thereby accelerating the process of vascular sclerosis. A high-fat diet can lead to elevated blood lipid levels and promote the deposition of fat in the liver and visceral areas, which can trigger insulin resistance and increase inflammatory reactions. Excessive energy intake can lead to obesity, especially with an increase in visceral fat closely related to metabolic abnormalities. Lack of physical activity is common in modern lifestyles, and sedentary behavior can reduce energy expenditure and affect the balance of glucose and lipid metabolism. Long-term lack of exercise can lead to a decrease in the muscle tissue's ability to absorb glucose, thereby increasing the risk of insulin resistance. Regular exercise can promote fat oxidation and improve blood lipid levels, while enhancing insulin sensitivity, making insufficient exercise an important risk factor for metabolic comorbidities. Sleep quality also affects metabolic health. Lack of sleep can affect the regulation of the endocrine system, such as increasing cortisol secretion and altering appetite-regulating hormone levels, which may lead to weight gain and elevated blood sugar. Long-term sleep disorders can also affect the balance of the autonomic nervous system, keeping the sympathetic nervous system in an excited state, thereby increasing blood pressure levels. Behavioral factors gradually accumulate over the long term and form a metabolic abnormal environment. When multiple adverse behaviors coexist, the probability of cardiovascular metabolic comorbidities increases significantly.

4. The impact of cardiometabolic comorbidities on ischemic stroke

4.1. Increased risk of stroke occurrence

Cardiovascular metabolic comorbidity plays a fundamental role in the occurrence of ischemic stroke, characterized by the long-term coexistence and mutual reinforcement of multiple metabolic abnormalities

in the same body, thereby forming a sustained vascular injury environment. Hypertension, diabetes, dyslipidemia, obesity, and other metabolic disorder factors form a complex pathological network in the human body. These abnormal factors work together on the structure and function of the vascular wall, and gradually promote the development of cerebral atherosclerosis. When multiple risk factors coexist in the same individual, the damage burden borne by vascular endothelial cells is significantly increased, and the inflammatory response of the vascular wall persists and gradually intensifies, ultimately leading to vascular structural remodeling and hemodynamic abnormalities. Long-term existence of hypertension can generate sustained mechanical pressure on the cerebral artery wall, causing dysfunction of endothelial cells and increasing the probability of low-density lipoprotein deposition in the vascular wall. Diabetes related hyperglycemia can promote protein glycosylation and oxidative stress; these metabolic changes damage vascular endothelial cells and induce an inflammatory cascade reaction. Dyslipidemia provides a key lipid source for the formation of atherosclerotic plaque. Low-density lipoprotein cholesterol can be oxidized and modified after being deposited under the vascular endothelium. Oxidized low-density lipoprotein further stimulates macrophages to phagocytosis and form foam cells, thus forming the core structure of atherosclerosis. When multiple metabolic abnormalities coexist, the rate of vascular wall damage is significantly accelerated, and the speed and volume of plaque formation show a significantly increasing trend. With the gradual development of atherosclerosis, the degree of cerebral vascular lumen stenosis is increasing. When hemodynamic conditions change or plaque stability decreases, the risk of thrombosis is significantly increased. Insulin resistance plays an important role in cardiovascular metabolic comorbidities, which can lead to lipid metabolism disorders and increased inflammatory responses. Triglyceride glucose index is considered an important index to evaluate the degree of insulin resistance, and its elevation often indicates that individuals have a higher risk of atherosclerosis. Research has found that as the number of metabolic abnormalities gradually increases, the risk of ischemic stroke increases exponentially. The vascular injury environment formed by the synergistic effect of multiple factors keeps the cerebral vascular system in a vulnerable state for a long time. When blood flow decreases or thrombosis forms, brain tissue is prone to ischemic necrosis. The increase in the number of metabolic abnormalities is also related to the increase in the level of systemic inflammatory reaction. Chronic inflammatory reaction will further promote the progression of atherosclerosis and weaken the ability of vascular repair. As metabolic abnormalities persist, the cerebrovascular system gradually loses its normal regulatory ability, leading to a decrease in cerebral blood flow reserve and making brain tissue more susceptible to ischemic damage during blood flow fluctuations.

4.2. Increased risk of recurrence

Ischemic stroke patients enter a long-term recurrence risk period immediately after their first onset, and recurrent stroke often leads to more severe neurological damage and higher disability rates. Cardiovascular metabolic comorbidity plays an important role in the process of stroke recurrence, and its influence is mainly reflected in the persistent atherosclerotic environment and the tendency toward thrombosis. After a stroke event, the metabolic abnormalities in the patient's body usually persist. If blood pressure, blood sugar, and blood lipid control fail to reach the ideal level, atherosclerosis will continue to progress. Hypertension plays a crucial role in the process of stroke recurrence. Continuously elevated blood pressure can lead to structural changes in cerebral arterioles, thickening of vessel walls, and appearance of hyaline changes. These changes can weaken vessel elasticity and increase the risk of vessel rupture or occlusion. Diabetes related

hyperglycemia will also accelerate the process of vascular disease. Hyperglycemia can promote the formation of protein glycation end products, which will deposit in the vascular wall and cause an inflammatory reaction, thus leading to sustained impairment of vascular endothelial function. Dyslipidemia continued to provide a lipid source for plaque growth. After the size of atherosclerotic plaque gradually increased, the stability of fiber cap on the surface of the plaque decreased, and the probability of plaque rupture significantly increased. The lipid core exposed after plaque rupture activates platelet aggregation and induces thrombosis, leading to new cerebrovascular occlusion events. Chronic inflammatory response also plays an important role in the mechanism of stroke recurrence, as inflammatory cell infiltration promotes necrosis within plaques and weakens their stability. Some patients may experience significant fluctuations in blood pressure after a stroke, and this increased variability in blood pressure can increase the degree of endothelial damage in cerebral blood vessels, making them more vulnerable. Metabolic abnormalities can also alter the coagulation state of blood, increase blood viscosity, and enhance platelet activation levels, thereby further increasing the probability of thrombosis formation. Over time, if the control of risk factors is not ideal, new atherosclerotic lesions will form in other vascular parts, making the patient's overall vascular system remain in a high-risk state. The recurrence of stroke is closely related to factors related to the patient's lifestyle, such as a high salt diet, lack of exercise, and smoking behavior, which may all contribute to the persistence of vascular damage. Metabolic comorbidities often require stricter risk factor control strategies after stroke; otherwise, the risk of recurrence will remain at a high level.

4.3. Aggravated severity of acute phase illness

Patients with cardiovascular metabolic comorbidities often exhibit more severe neurological deficits during the acute phase of ischemic stroke, which is closely related to decreased cerebral vascular reserve capacity and weakened collateral circulation compensation ability. Long-term metabolic abnormalities can lead to chronic changes in the structure of cerebral blood vessels, such as thickening of vessel walls, narrowing of vessel lumens, and decreased vascular elasticity. These structural changes result in a lack of effective compensatory ability for cerebral blood vessels when blood flow decreases. Under normal circumstances, when the main blood supply artery is partially narrowed or blocked, collateral circulation can maintain brain tissue perfusion to a certain extent. However, in a long-term metabolic abnormal environment, microvascular structure gradually undergoes degenerative changes, and small artery sclerosis and capillary sparsity phenomena gradually appear, which significantly weaken collateral circulation function. When cerebral blood vessels suddenly become blocked, brain tissue lacking effective collateral circulation support is more prone to rapid ischemic necrosis. High blood sugar levels also have an important impact on the process of acute brain injury. Elevated blood sugar levels increase lactate accumulation in ischemic brain tissue, which can lead to local acidosis and exacerbate neuronal damage. High blood sugar can also increase the permeability of the blood-brain barrier, making it easier for inflammatory cells to enter brain tissue and trigger secondary inflammatory reactions. Abnormal blood lipids in the acute phase may also affect the rheological properties of the blood. An increase in blood viscosity can reduce microcirculation perfusion efficiency, thereby expanding the ischemic range of the brain. Hypertensive patients are prone to blood pressure fluctuations during the acute phase, which may further affect cerebral perfusion stability and expand the ischemic area. Patients with metabolic comorbidities usually have higher levels of inflammation in their bodies, and the release of inflammatory mediators can promote oxidative stress response and accelerate neuronal damage. As ischemic injury progresses, the area of neuronal necrosis expands, and the clinical symptoms of patients

become more pronounced, such as limb weakness, language disorders, and more severe consciousness disorders. The severity of acute phase illness is closely related to later functional recovery. The larger the extent of early brain tissue damage, the more difficult it is to recover neurological function in the later stage.

5. Intervention and management strategies

5.1. Primary prevention

Primary prevention is the most fundamental and critical link in the prevention and control system of ischemic stroke combined with cardiovascular metabolic comorbidities. Its core goal is to systematically identify and continuously intervene in potential cardiovascular metabolic risk factors in the community population before stroke occurs, in order to reduce the damage caused by long-term accumulation of risk factors to the cerebrovascular system. Hypertension, diabetes, and dyslipidemia constitute the three core components of cardiovascular metabolic abnormalities. These three risk factors have a clear and continuous role in promoting the occurrence and development of ischemic stroke. Therefore, the primary prevention strategy must establish a systematic screening and management mechanism around these three metabolic abnormalities. At the level of the community health service system, a normalized chronic disease screening system should be established, incorporating blood pressure, fasting blood glucose, glycated hemoglobin, and blood lipid profile testing into routine health check-ups for community residents, forming a continuous dynamic monitoring mechanism. For individuals with a family history of stroke, obesity, sedentary lifestyle, smoking history, and poor dietary structure, they should be included as key monitoring subjects, and the screening frequency should be increased to early identify individuals in the stage of metabolic abnormalities. For people with blood pressure in the range of 130–139/85–89 mmHg, strict lifestyle management should be implemented, with controlling salt intake as the core. It is recommended to keep daily salt intake below 5 g while reducing the intake of high-sodium processed foods and encouraging food structures rich in potassium, magnesium, and dietary fiber, such as vegetables, fruits, and whole grains. For the pre-diabetes population with fasting blood glucose between 5.6–6.9 mmol/L or glycosylated hemoglobin 5.7%–6.4%, a structured weight management program should be developed to emphasize the correlation between body fat reduction and insulin sensitivity improvement, and the target body mass index should be controlled within the range of 18.5–23.9 kg/m². Exercise intervention should have clear planning, and it is recommended to engage in moderate-intensity aerobic exercise for at least 150 minutes per week, such as brisk walking, cycling, or swimming, supplemented by 2–3 sessions of resistance training per week to enhance muscle metabolism. For people with dyslipidemia, the intervention intensity should be determined according to the risk assessment results of atherosclerotic cardiovascular disease. Those with LDL cholesterol levels more than 3.4 mmol/L should start diet regulation and weight management plans, and high-risk individuals need to consider early drug intervention. The primary prevention system should also strengthen public health education, enhance the population's awareness of the long-term cumulative effects of stroke risk factors, and enable individuals to actively participate in health management. Grassroots medical institutions should establish electronic health records for chronic diseases to achieve long-term recording and trend evaluation of blood pressure, blood glucose, and blood lipid indicators, so that doctors can identify metabolic risk changes in a timely manner during follow-up. The public health management department also needs to combine community resources to carry out health promotion activities, such as salt control actions, smoking cessation intervention projects, and weight management plans, in order to gradually improve the overall lifestyle structure of the community.

Early identification and continuous management of metabolic risk factors can delay the progression of vascular endothelial injury and atherosclerosis, reduce the risk of cerebrovascular stenosis and thrombosis, and thus reduce the overall incidence of ischemic stroke before the onset of disease.

5.2. Secondary prevention

Secondary prevention is aimed at patients who have had an ischemic stroke. Its core goal is to reduce the recurrence rate of stroke and reduce the risk of other atherosclerotic cardiovascular events. When stroke patients enter the long-term management stage after the acute phase, they are often accompanied by a variety of cardiovascular metabolic abnormalities. Elevated blood pressure, glucose metabolism disorders, and lipid metabolism abnormalities jointly promote vascular endothelial dysfunction and the progression of atherosclerotic plaque. Therefore, more stringent risk factor control strategies must be adopted for secondary prevention. Antiplatelet therapy constitutes the basic measure for long-term prevention of non-cardiogenic ischemic stroke, and commonly used drugs include aspirin or clopidogrel. Its mechanism of action is to inhibit platelet aggregation and reduce the risk of thrombosis. For high-risk patients, a dual antiplatelet strategy can be used in the short term to reduce the probability of early recurrence, but it needs to be evaluated in conjunction with bleeding risk. Lipid-regulating therapy is a core component of secondary prevention. Statins can not only reduce the level of low-density lipoprotein cholesterol but also stabilize atherosclerotic plaque and improve vascular endothelial function. The LDL-C control target for stroke patients should usually be below 1.8 mmol/L, and high-risk individuals can further control it to below 1.4 mmol/L to reduce the probability of plaque rupture and thrombus formation. Blood pressure management also plays an important role, and maintaining long-term blood pressure levels below 130/80 mmHg can help reduce cerebral small vessel damage and the progression of arteriosclerosis. Individualized drug selection for antihypertensive treatment should be based on the patient's underlying disease condition. Commonly used drugs include angiotensin-converting enzyme inhibitors, angiotensin II receptor antagonists, calcium channel blockers, and diuretic combinations. The blood glucose management of diabetes patients needs to focus on the level of glycosylated hemoglobin, and the control goal is usually set below 7%, while avoiding adverse effects of hypoglycemic events on brain function. Regular monitoring of liver function, kidney function, and electrolyte levels should be conducted during drug therapy to evaluate long-term drug safety. The secondary prevention system also needs to strengthen the dynamic assessment of stroke risk factors and regularly conduct carotid ultrasound or vascular imaging examinations to understand the progression of vascular lesions. The frequency of patient follow-up is usually recommended to be evaluated every 1–3 months in the early stages after stroke, and the stable period can gradually be extended to once every 6 months. Medical institutions should establish a stroke follow-up management system to continuously record patients' blood pressure, blood glucose, blood lipid levels, and medication compliance to ensure long-term stability of risk factor control objectives. Systematic secondary prevention management can reduce the progression rate of atherosclerosis and the risk of recurrent cerebral infarction, which is of great significance in improving the long-term survival rate and functional outcome of stroke patients.

5.3. Multidisciplinary management model

Ischemic stroke patients with cardiovascular metabolic comorbidities often involve pathological changes in multiple organ systems, and a single specialized medical model is difficult to cover all the diagnostic and treatment needs. Therefore, multidisciplinary collaborative diagnosis and treatment models have

gradually become an important form of management for complex stroke patients. Multidisciplinary teams are usually led by neurologists as the core coordinator, while integrating experts from multiple professional fields such as cardiology, endocrinology, nephrology, nutrition, rehabilitation, clinical pharmacy, and psychology to participate in patient diagnosis and treatment decisions. Neurologists are mainly responsible for the diagnosis of stroke itself, acute phase management, and the development of long-term secondary prevention strategies, as well as evaluating changes in cerebrovascular imaging and neurological function recovery. Cardiologists focus on evaluating whether patients have structural and functional abnormalities in the heart, such as coronary artery disease, arrhythmia, or heart failure. Especially for patients with atrial fibrillation, it is necessary to determine whether to initiate anticoagulant therapy to reduce the risk of cardioembolic embolism. Endocrinologists are responsible for the fine management of diabetes and other metabolic diseases, selecting the appropriate combination of hypoglycemic drugs according to the patients' islet function, and monitoring the development of microvascular complications in diabetes. Nephrologists pay attention to the impact of chronic renal dysfunction on drug metabolism and blood pressure control, and adjust renal protection treatment plans. Nutritionists develop personalized dietary plans based on the patient's metabolic status, body mass index, and blood lipid levels to ensure a reasonable energy intake structure and reduce high-fat and high salt food intake. The rehabilitation medicine team is responsible for assessing post-stroke motor dysfunction, swallowing function issues, and decreased daily living abilities, and developing a systematic rehabilitation training plan to promote neurological recovery. Clinical pharmacists are responsible for drug safety assessment during multi-drug combination therapy, identifying potential drug interactions, and optimizing drug dosage. Psychological experts assess common anxiety, depression, or cognitive impairments after stroke and provide corresponding psychological interventions. Multidisciplinary teams typically use regular case discussions to develop a unified diagnosis and treatment plan for complex patients, avoiding conflicts between different specialized treatment plans. Medical institutions can also establish comprehensive stroke management clinics, concentrating multiple specialized resources on the same diagnosis and treatment platform to provide patients with continuous medical services. The multidisciplinary collaboration model strengthens information sharing and decision-making coordination among various professions, which helps to improve the overall management efficiency of complex stroke patients and reduce duplicate examinations or unnecessary treatments.

6. Conclusion

This study systematically analyzed clinical data from 864 patients with ischemic stroke, comprehensively and deeply revealing the severe status of Cardiometabolic comorbidity (CMC) in this patient population and its profound impact on clinical outcomes. The core conclusions of the study can be summarized as follows.

In summary, the findings of this study provide important insights for clinical practice and public health strategies. Faced with the severe challenge of ischemic stroke combined with cardiometabolic comorbidities, medical officials must shift from the traditional, single-disease-centered diagnosis and treatment model to a patient-centered, comprehensive management model that addresses multiple comorbidities. The core recommendations are as follows: medical officials must vigorously strengthen systematic screening and assessment of comorbidities in stroke patients, and on this basis, develop and implement individualized comprehensive management plans for each patient by enhancing lifestyle intervention, optimizing pharmacotherapy for multiple risk factors, and promoting the multidisciplinary team (MDT) model. Only in

this way can medical officials effectively mitigate the significant harm caused by comorbidities, genuinely improve the quality of life and long-term prognosis of tens of millions of ischemic stroke patients in China, and thus contribute to achieving the ambitious goals of “Healthy China 2030.”

Disclosure statement

The authors declare no conflict of interest.

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Construction and Application of a “Five-Proactive” Predictive Nursing Management System in A Tertiary Hospital: A Practice Innovation for High-Quality Development

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Abstract: *Background:* Under the National Health Commission’s Further Improvement of Nursing Service Action Plan (2023–2025) and the context of high-quality development in public hospitals, traditional reactive nursing models have shown limitations in patient safety and quality outcomes. *Objective:* To develop and implement a predictive nursing management system integrating “Prediction–Early Warning–Prevention–Emergency Response” and a supporting “Five-Prevention System” (risk prediction, safety early warning, proactive prevention, emergency preparedness, and practical simulation). *Methods:* Taihe Hospital, a large tertiary hospital in Shiyan, China, systematically introduced a predictive nursing model starting in 2024. Interventions included tiered training (14 themes, 648 sessions, 19,622 nurse attendances), information technology upgrades (I-EWS, tri-color risk warning system), risk stratification (unit/nurse manager/nurse levels), performance incentives, and regular emergency drills. Outcome indicators included adverse event reporting, complication rates, length of stay, and patient/nurse satisfaction. *Results:* After implementation, the proportion of reported grade-IV adverse events significantly increased (indicating earlier detection of potential risks). Elective surgery complication rates, unplanned readmission rates, and average length of stay all decreased. Nurse professional value and patient satisfaction improved markedly. Several serious adverse events (e.g., postoperative neck hematoma leading to airway compression) were prevented through early warning and intervention. *Conclusions:* The predictive nursing “Five-Prevention System” is feasible and effective in shifting nursing practice from reactive to proactive, improving patient safety and nurse empowerment. The model provides a replicable pathway for nursing management transformation in large public hospitals.

Keywords: Predictive nursing; Five-Prevention System; Patient safety; Nursing quality; High-quality development of public hospitals

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1. Background

With the deepening of China's healthcare system reform and the promotion of high-quality development in public hospitals, the connotation and scope of nursing services are undergoing profound changes ^[1]. The World Health Organization's Global Patient Safety Action Plan 2021–2030 also sets the core vision of minimizing avoidable harm and providing safer care for all. However, nursing practice still faces the limitations of a “passive-reactive” model: nurses primarily execute medical orders, lack forward-looking assessment and decision-making, experience low professional recognition and high burnout, and bear great pressure in managing high-risk patients ^[2]. Meanwhile, the shift to DRG/DIP payment systems requires the nursing role to transform from “executor” to “value manager”, with nursing services moving upstream to participate in cost control and complication prevention ^[3]. Therefore, how to innovate nursing management models, unleash nurses' potential, and enhance their key role in ensuring medical quality and safety has become an urgent issue in the high-quality development of public hospitals.

Predictive nursing is defined as a model in which nurses comprehensively analyze and judge patients' conditions and potential risks through situational awareness, identify existing and potential nursing problems, and implement corresponding measures to effectively prevent deterioration or complications ^[4]. Its core lies in anticipating possible adverse reactions based on the laws of disease onset, progression, and changes, enabling early detection, early prevention, and early treatment, thereby making nursing work proactive rather than reactive ^[5].

As a large tertiary general hospital, Taihe Hospital has systematically promoted the construction of a predictive nursing management model since 2024, driven by both national policies and disciplinary development. Focusing on “ensuring safety, improving quality, enhancing service, and increasing efficiency”, the hospital has developed a distinctive “Five-Prevention System” for predictive nursing, forming a closed-loop operational mechanism from concept to action, training to practice, and management to incentives. This paper systematically describes the innovative concepts, implementation pathways, and outcomes of predictive nursing at Taihe Hospital, aiming to provide a reference for the transformation of nursing management models in public hospitals.

2. Innovative concepts

The essence of predictive nursing lies in the character “pre-” (prevention, prediction): through forward-looking risk assessment and intervention, the focus of nursing work shifts from post-event remediation to pre-event prevention, striving to let “prediction” avoid “encountering” adverse events. Based on this concept, Taihe Hospital innovatively constructed a predictive nursing management framework of “Prediction–Early Warning–Prevention–Emergency Response”, and further refined the core connotations of the “Five-Prevention System”: risk prediction, safety early warning, proactive prevention, emergency preparedness, and practical simulation.

Risk prediction is the starting point. Nurses identify high-risk patients (major surgery, critical illness, multiple comorbidities) and anticipate possible nursing risks through comprehensive analysis.

Safety early warning is the key transmission link. The hospital developed an early-warning threshold manual, introduced information technology-based early warning measures, and established risk warning thresholds and intelligent reminder mechanisms based on clinical information, ensuring nurses can detect early signs of deterioration.

Proactive prevention is the ultimate goal. Combined with quality monitoring indicators, innovative clinical techniques, targeted improvement of safety hazards, and clinical nursing pathways are implemented to deliver precise preventive measures.

Emergency preparedness is the safeguard system. Cross-department emergency response channels are kept open, and all nurses are required to achieve competence in emergency skills, ensuring “preparedness prevents adversity.”

Practical simulation is an important means of competence testing. Regular emergency drills and scenario-based simulations hone nurses’ emergency response and practical operation abilities, enabling them to respond calmly when real risks arise.

The construction of the “Five-Prevention System” has driven three fundamental shifts in nursing work: from passive execution to active management, from problem-driven to risk-driven, and from experience-based to evidence-based nursing. The essence of this transformation is moving the focus of nursing work from “problems that have already occurred” to “risks that may occur”, reshaping the nurse’s role from “order executor” to “patient safety guardian”^[6].

3. Implementation pathways

3.1. Top-level design: Integration into hospital development strategy

Taihe Hospital incorporated predictive nursing into its overall development strategy. Under the “Efficiency Improvement Year” initiative, the hospital formulated the Implementation Plan for Promoting Predictive Nursing in Taihe Hospital, defining a two-year construction period with five progressive stages: systematic training, full implementation, mid-term supervision, outcome evaluation, and continuous improvement.

Financial support was fully provided: the 2025 nursing budget allocated CNY 2 million for nursing information system construction, CNY 850,000 for nursing training, CNY 800,000 for nursing specialty development, CNY 800,000 for traditional Chinese medicine nursing, CNY 600,000 for advanced study, CNY 1.08 million for academic exchanges, CNY 300,000 for awards and recognition, and CNY 500,000 for nursing equipment — forming a complete support chain from hardware investment and talent cultivation to academic development.

In terms of management structure, the hospital follows a vertical “decision- management-execution-implementation” system to ensure that predictive nursing concepts effectively penetrate every clinical unit. The Nursing Department incorporated predictive nursing into the comprehensive nursing target management system, signing responsibility agreements with head nurses of all wards, clarifying assessment indicators and scoring standards. In the 2025 nursing comprehensive target management framework, the predictive nursing special assessment accounts for 21 points, covering eight dimensions, including nursing service indicators, inpatient satisfaction, responsible nurse satisfaction, voluntary adverse event reporting, and detection and elimination of major safety hazards, thereby shifting from passive accountability to active empowerment and from post-event remediation to pre-event prevention.

3.2. Stratified management: precise implementation with tailored strategies

To enhance the operability and specificity of predictive nursing implementation, Taihe Hospital established a multi-level stratified management system.

Nursing unit level: According to the severity and risk of patients and nurses' workload, all units were divided into three categories (I, II, III), with differentiated management requirements and assessment standards.

Head nurse level: Based on specialty characteristics, patient criticality, workload, etc., head nurse positions were classified as A or B, with clear indicators, regular assessment, and dynamic adjustment.

Nurse level: Based on professional competence, work quality, and technical title, clinical nursing positions were graded from N0 to N5, enabling refined management of job competencies.

Through stratified management, the hospital ensured that "every person has a goal and every shoulder bears a responsibility", laying the organizational foundation for full implementation of predictive nursing.

3.3. Training empowerment: systematic cultivation of predictive thinking

The core of predictive nursing competence lies in nurses' clinical thinking and risk identification ability, which requires systematic training. Taihe Hospital identified 14 major training themes covering symptom recognition of critical emergencies such as stroke, myocardial infarction, acute pulmonary embolism, and aortic dissection. Nursing management teams visited each clinical department to deliver training. During 2024–2025, 648 training sessions were conducted, with a total attendance of 19,622 nurse-times, essentially covering all nurses in the hospital. Training content included theoretical lectures, clinical case analyses, and scenario-based simulations, solidifying nurses' emergency knowledge reserve, enhancing risk awareness, and cultivating predictive thinking.

Concurrently, the hospital conducted 1,779 skill assessments in emergency procedures and 49 emergency drills. Through "assessment to promote learning, drills to promote application", nurses' emergency response and practical abilities were honed, ensuring that theoretical knowledge and clinical skills translate into core competencies. In 2025, a Predictive Nursing Application Ability Competition was held, using simulated clinical scenarios to comprehensively evaluate participants' clinical application of predictive nursing. Additionally, a Nursing Condition Observation Competition and a Critical Patient Risk Emergency Competition were conducted, with on-site scenario simulations integrating real cases, where 24 excellent nurses competed, fostering a positive atmosphere of "combining competition with training, promoting learning through competition."

3.4. Information technology support: enhancing early warning accuracy

Information technology is a crucial enabler of predictive nursing. Taihe Hospital introduced and developed multiple information systems to significantly improve the accuracy and efficiency of nursing risk identification through data integration, intelligent analysis, and efficient linkage. The hospital upgraded its nursing information system to achieve early risk identification and intelligent reminders; established an I-EWS risk management process based on the CIS system to enable dynamic monitoring and graded early warning of patient deterioration; introduced an early warning management system and a BI nursing data extraction system to provide data support for nursing decisions; and developed an "Overview at a Glance" system for centralized display and efficient linkage of multi-source information.

In practice, the hospital constructed a tri-color early warning management pathway for high-risk nursing patients. Based on urgency and special patient characteristics, risk levels are categorized as: Red (high risk) — critically ill or life-threatening patients, tracked by head nurses for implementation of high-risk measures, with follow-up by deputy director of nursing within 24 hours; Yellow (medium risk) — seriously

ill patients requiring close monitoring, tracked by head nurses of larger units within 24 hours; Green (low risk) — recovering patients with potential risks, tracked by head nurses for implementation of measures, with management strategies adjusted as risk level changes. The tri-color warning system enables dynamic risk grading, precise intervention, and closed-loop management, transforming traditional post-event handling into pre-event warning and intra-event intervention.

3.5. Risk prediction: Comprehensive process review and standardization

Risk prediction is the foundation of predictive nursing. Taihe Hospital established a “regular + timely” mechanism for risk prediction, conducting annual safety hazard inspections and nursing risk reviews covering 272 items. Hospital-wide, 11 risk assessment tools were integrated. Based on high-risk diseases and patients prone to critical deterioration or serious complications, early warning prompts were provided from multiple dimensions (symptoms, signs, laboratory indicators, vital signs) to guide nurses in rapid identification, response, and management of emergencies. At the same time, 168 “one department, one strategy” nursing risk prevention plans were developed, listing key preventive measures in a checklist format to ensure clear risk prevention protocols for each department and patient. At the specialty level, specialty-specific nursing risk early warning manuals were formulated, systematizing and manualizing early warning signals and response strategies for various diseases for easy reference by clinical nurses.

3.6. Performance incentives: A balanced system of rewards and accountability

Performance management is an important lever for promoting predictive nursing implementation. Taihe Hospital established a predictive nursing performance assessment system and a secondary performance distribution plan for nursing units, incorporating key predictive nursing indicators into comprehensive nursing target assessments and strictly auditing performance distribution. The hospital’s 2025 Quality Control Implementation Plan specifies that quality performance accounts for 30% of department performance, with department quality control scores directly linked to the proportion of quality performance achieved. This design transforms predictive nursing from a “soft task” into a “hard indicator” and from an “advocacy requirement” into an “accountability constraint.”

On the positive incentive side, the hospital established a weekly “Predictive Nursing Typical Case” sharing system and organized “Predictive Nursing Case Sharing” activities. Based on clinical practice and typical cases, the activities demonstrated the entire process from risk prediction and early warning to preventive measures. Model predictive nursing departments and demonstration departments were selected, using benchmarking to stimulate enthusiasm and creativity across the hospital. A series of reports on typical predictive nursing cases was published via the hospital’s WeChat official account and other channels, enhancing nurses’ professional confidence and sense of professional value. The hospital’s Party Committee Secretary summarized at a typical case light-and-shadow exhibition: “The professional value of nursing is seen.” This incentive-centered cultural approach enables nurses to truly grow from “executors” into “predictors” and “guardians” of patient safety.

4. Outcomes

4.1. Significant improvement in nursing quality and patient safety

After the implementation of predictive nursing, Taihe Hospital achieved comprehensive improvements in

nursing quality and patient safety indicators. The proportion of reported grade-IV adverse events increased significantly, indicating that more potential safety hazards were detected and intervened upon early, achieving a forward shift of the safety threshold. Elective surgery complication rates, unplanned readmission rates, and average length of stay all decreased, and the incidence of disease and care-related complications was markedly reduced. Specific examples include: through predictive early warning nursing, multiple cases of unplanned return to surgery were avoided; 35 medication safety early warnings were issued; and numerous condition-observation early warning cases emerged. For instance, in the central operating room, a circulating nurse noticed a patient's bilateral neck "progressive" swelling after neck surgery. Relying on her professional knowledge and deep understanding of postoperative complication risks, she adhered to the principle of "no resolution, no rest", promptly reported and escalated the warning, successfully preventing the patient from developing airway compression due to hematoma and thereby avoiding a life-threatening event. These vivid cases fully demonstrate the unique value of predictive nursing in ensuring patient safety and preventing serious adverse events.

4.2. Dual improvement in nurses' professional value and patient satisfaction

After the adoption of predictive nursing management, both physician satisfaction and inpatient satisfaction increased significantly. National public hospital performance assessment results showed a continuously improving patient experience. More importantly, predictive nursing shifted nurses from traditional "order executors" to "safety guardians" and from "passive response" to "active prediction", fully recognizing and highlighting nurses' professional value. The series of initiatives — typical case reports, model department selection, and skill competitions — effectively enhanced nurses' sense of professional achievement, confidence, and belonging, positively alleviating burnout and stabilizing the nursing workforce.

4.3. Industry recognition and demonstration effects

Taihe Hospital's innovative predictive nursing practice has received high recognition from within and outside the healthcare industry. During 2024–2025, the hospital received two "Innovative Practice Cases in Healthcare Quality and Efficiency Improvement" awards from the National Health Commission's Institute of Hospital Management, as well as a first prize, second prize, and best organization award in the Geriatric Rehabilitation Nursing Case Competition of the Chinese Rehabilitation Medicine Association, and an "Excellent Work Award" from the Hubei Provincial Nursing Society. Additionally, five research projects were submitted for funding, five related papers were published, and four utility model patents were successfully granted, initially forming a virtuous cycle of mutual promotion between theoretical research and practical application.

5. Discussion and future directions

The construction and implementation of the predictive nursing "Five-Prevention System" at Taihe Hospital provides a replicable pathway for transforming nursing management models in large public hospitals. Reflecting on the process, several insights can be drawn.

First, predictive nursing competence is cultivable. Taihe Hospital's experience shows that through systematic, hospital-wide training and empowerment, supplemented by practical drills and scenario simulations, nurses' risk awareness and predictive thinking can be significantly improved. Only by

continuously infusing nursing staff with new knowledge, skills, and ways of thinking can the vitality and effectiveness of predictive nursing be maintained.

Second, identifying key elements is critical for improving predictive nursing capability. Effective implementation requires focusing on: identifying key patients (major surgery, critical illness, multiple comorbidities), defining key measures (accurate condition assessment, evidence-based nursing plans, attention to key indicators, establishing warning thresholds), and developing monitoring indicators with regular indicator-driven analysis and improvement. Only by accurately grasping the core elements of predictive nursing can tangible results be achieved in ensuring patient safety and improving specialty nursing quality.

Third, information technology provides essential technical support. Through the introduction and development of multiple information systems, Taihe Hospital achieved early risk identification, dynamic monitoring, and intelligent early warning, significantly improving warning accuracy and intervention efficiency. Practice has proven that deep integration of information technology and nursing management is an important engine driving predictive nursing from concept to practice ^[7].

Fourth, institutional and cultural construction ensure the long-term sustainability of predictive nursing. Taihe Hospital incorporated predictive nursing into comprehensive target management and performance evaluation systems, establishing a full-chain incentive mechanism from job-based stratified management to secondary performance distribution. As a result, a nursing safety culture of “active prediction and precise prevention” has taken root throughout the hospital. When predictive thinking becomes every nurse’s work habit, nursing practice truly shifts from “passive execution” to “active management” and “proactive intervention” ^[8].

Several challenges remain. Data quality of information systems needs further improvement; the accuracy of predictive nursing decisions requires more evidence-based support; and implementation outcomes vary across departments. In the future, Taihe Hospital will continue to deepen the predictive nursing system, conducting further research on intelligent early warning model development, multidisciplinary collaboration models, and predictive nursing evaluation standards, further unlocking nurses’ potential, leveraging nursing’s professional value, and contributing nursing strength to the high-quality development of public hospitals.

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Disclosure statement

The authors declare no conflict of interest.

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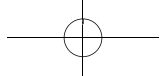
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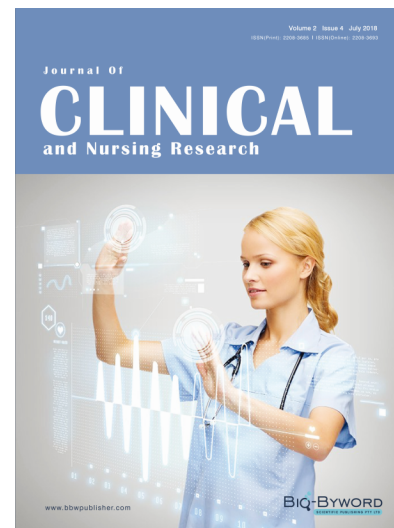
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