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Advances in Left Ventricular Noncompaction and Its Prevention and Treatment with Traditional Chinese Medicine

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Abstract: ***Left Ventricular Noncompaction (LVNC) is a congenital cardiomyopathy characterized by excessively prominent trabeculations and deep intertrabecular recesses within the ventricular cavity. Modern medical management primarily focuses on symptomatic treatment, lacking specific therapeutic agents. In contrast, Traditional Chinese Medicine (TCM), based on the therapeutic principle of "Supplementing Qi and Warming Yang, Activating Blood and Promoting Diuresis, " demonstrates distinct advantages. It employs multi-component, multi-target interventions to regulate myocardial energy metabolism, suppress inflammatory responses, and ameliorate myocardial fibrosis. The integrated approach of TCM and Western medicine offers a more comprehensive therapeutic strategy for patients with LVNC. Future research should prioritize high-quality clinical studies and in-depth mechanistic exploration.***

Keywords: Left Ventricular Noncompaction (LVNC), Traditional Chinese Medicine (TCM), Benefiting Qi and Warming Yang, Activating Blood and Resolving Stasis, Myocardial Fibrosis, Integrated Traditional and Western Medicine**.**

1. Introduction

LVNC is a rare genetic cardiomyopathy caused by the failure of the myocardial compaction process during embryonic development. It is characterized by prominent trabeculations and deep intertrabecular recesses within the ventricular cavity [1]. The clinical presentation primarily includes heart failure, arrhythmias, thromboembolism, and sudden cardiac death, with a high associated mortality rate. In recent years, the widespread adoption and advancement of imaging techniques, such as echocardiography and cardiac magnetic resonance (CMR), have significantly improved the diagnostic rate of LVNC. However, its pathogenesis has not been fully elucidated, and targeted treatment options remain limited.

LVNC is a congenital cardiomyopathy characterized by excessively prominent trabeculations and deep intertrabecular recesses within the ventricular cavity. Currently, modern medical management for LVNC primarily adheres to the general principles for treating heart failure and arrhythmias. This includes the use of medications such as Angiotensin-Converting Enzyme Inhibitors (ACEIs), beta-blockers, and anticoagulants. Severe cases may require cardiac resynchronization therapy (CRT), implantable cardioverter-defibrillators (ICDs), or even heart transplantation. However, these approaches can only alleviate symptoms rather than reverse the underlying myocardial structural abnormalities, and the prognosis for some patients remains unsatisfactory.

In contrast, TCM is characterized by its holistic approach, which integrates pattern differentiation and disease differentiation to guide treatment. This confers unique advantages in delivering personalized therapy for refractory diseases with individual variations. In TCM theory, LVNC can be classified under categories such as "Chest Impediment" and "Heart Failure". Its pathogenesis is primarily rooted in the deficiency of Heart Qi, Blood, Yin, and Yang, with blood stasis, phlegm-turbidity, and water fluid constituting the secondary manifestations. Through therapeutic strategies such as "Supplementing Qi and Warming Yang, Activating Blood and Resolving Stasis, Promoting Diuresis and Expelling Fluid Retention," TCM can effectively improve cardiac function, alleviate symptoms, and enhance the quality of life for patients.

This article aims to review recent advances in both Western and Chinese medicine regarding LVNC, thereby providing a theoretical basis and clinical insights for the integrated prevention and treatment of LVNC.

2. Advances in Modern Medical Research

2.1 Epidemiological and Genetic Mechanisms

LVNC was previously considered a rare disease; however, its detection rate has been steadily increasing in recent years due to continuous advancements in diagnostic techniques. LVNC demonstrates a familial predisposition but can also occur sporadically. Its prevalence in the general population is approximately 0. 05% to 0. 25%, accounting for about 3% to 4% of all cardiomyopathies. LVNC can present at any age, with a higher incidence observed in children and adolescents. The prevalence is slightly higher in males than in females [2].

LVNC exhibits significant genetic heterogeneity, with over 40 genes implicated in its pathogenesis. The most commonly associated genes include TTN (encoding titin), MYH7 (encoding beta-myosin heavy chain), and LMNA (encoding lamin A/C) [3]. Mutations in these genes primarily disrupt the development, contraction, and energy metabolism of cardiomyocytes, leading to abnormal myocardial structure. The inheritance pattern of LVNC is predominantly autosomal dominant, though rare cases of autosomal recessive and X-linked inheritance have also been reported [4].

2.2 Pathophysiology and Clinical Manifestations

The pathophysiological alterations in LVNC primarily stem from the abnormally prominent trabeculations and deep intertrabecular recesses. This abnormal architecture leads to reduced myocardial perfusion, microcirculatory dysfunction, consequently triggering myocardial ischemia and fibrosis. Simultaneously, impaired motion of the affected ventricular wall results in compromised systolic and diastolic function, reduced cardiac output, and ultimately leads to heart failure [5]. Furthermore, the deep recesses between trabeculae are prone to thrombus formation, which can embolize and cause thromboembolic events in organs such as the brain, kidneys, and lungs [6].

Myocardial fibrosis and electrophysiological abnormalities constitute the substrate for arrhythmias and sudden cardiac death [7].

The clinical manifestations of LVNC are highly diverse and vary in severity. Heart failure is the most common presentation, with patients exhibiting symptoms such as dyspnea, fatigue, and edema. Arrhythmias, including atrial fibrillation, ventricular premature complexes, ventricular tachycardia, or even ventricular fibrillation, can cause palpitations, syncope, or sudden death. Thromboembolic events may present as stroke or pulmonary embolism. Some patients may remain asymptomatic and are only identified through familial screening or incidental findings during physical examination. Pediatric patients often present with extracardiac manifestations, such as developmental delay and facial dysmorphism.

2.3 Diagnosis and Differential Diagnosis

The diagnosis of LVNC primarily relies on imaging examinations, with echocardiography being the preferred initial modality [8]. Commonly used diagnostic criteria include the Jenni, Chin, and Petersen criteria: the Jenni criteria require a ratio of trabeculated to non-trabeculated myocardium >2 (>1.4 in children) and evidence of deep recesses communicating with the ventricular cavity [9]; the Chin criteria emphasize the predominant location of trabeculations in the apical, lateral, and inferior walls [10]; the Petersen criteria utilize a ratio of non-compacted to compacted myocardial layer thickness at end-diastole >2.3 [11]. Cardiac magnetic resonance (CMR) can more clearly delineate myocardial structural features and assess myocardial fibrosis (via late gadolinium enhancement sequences), proving particularly valuable for diagnostically challenging cases. Endomyocardial biopsy remains the gold standard for diagnosing myocardial inflammation. Myocarditis is a potential differential diagnosis in cases of suspected LVNC. Myocardial biopsy may be warranted in cases with rapid progression despite standard therapy to rule out specific etiologies. Its findings can guide specific therapeutic decisions, particularly in cases of giant cell myocarditis or cardiac sarcoidosis [2]. However, due to its invasive nature and other logistical constraints, it is performed relatively infrequently.

LVNC can be differentiated from the following conditions. Dilated cardiomyopathy which also presents with cardiac dilation and impaired systolic function lacks the characteristic trabeculated morphology. Hypertrophic cardiomyopathy is characterized by myocardial thickening without deep recesses. Endocardial fibroelastosis is featuring endocardial thickening and ventricular cavity obliteration. And left ventricular false tendons which are cord-like structures rather than a meshwork of trabeculae [12]. Additionally, the athlete's heart may also exhibit myocardial thickening and trabeculation, but it is typically not associated with symptoms of heart failure.

2.4 Contemporary Treatment Strategies

Contemporary management of LVNC is primarily symptomatic and supportive, aiming to improve cardiac function and prevent complications. Pharmacological management includes: 1) guideline-directed medical therapy (GDMT) for heart failure, such as ACEIs/ARBs/ARNIs, beta-blockers, SGLT2 inhibitors, and diuretics [13]; 2) anticoagulation therapy for patients with a risk of or prior thromboembolic events; and 3) antiarrhythmic drugs, such as amiodarone or beta-blockers.

Non-pharmacological interventions include: 1) implantable devices, specifically implantable cardioverter-defibrillators (ICDs) for primary or secondary prevention of sudden cardiac death and cardiac resynchronization therapy (CRT) for patients with ventricular dyssynchrony; 2) left ventricular assist devices (LVADs), which serve either as a bridge to transplantation or as destination therapy, and 3) heart transplantation, reserved for patients with end-stage heart failure. As shown in Table 1.

Table 1: Modern Medical Treatment Strategies and Representative Drugs for LVNC

Treatment Category	Representative Drugs/Devices	Mechanism of Action	Indications
ACEI/ARB /ARNI	Enalapril, Valsartan, Sacubitril/Valsartan	Inhibit the RAAS, reduce cardiac afterload	First-line treatment for heart failure
β-Blockers	Metoprolol, Bisoprolol	Decrease heart rate, reduce myocardial oxygen consumption	Heart failure, arrhythmia
SGLT2 Inhibitors	Empagliflozin, Dapagliflozin	Promote natriuresis and diuresis, improve metabolism	Adjuvant treatment for heart failure
Anticoagulants	Warfarin, Rivaroxaban	Prevent thrombosis formation	Atrial fibrillation, history of previous embolism
Device Therapy	ICD、CRT	Prevent sudden cardiac death, improve ventricular	Ventricular arrhythmia, ventricular asynchrony
End-Stage Treatment	Heart Transplantation	Replace the diseased heart	End-stage heart failure

Although the aforementioned treatments can improve symptoms and prognosis to a certain extent, none of them can reverse myocardial structural abnormalities. In recent years, molecular targeted therapy and gene therapy have become research hotspots, such as drugs targeting specific signaling pathways (e.g., TGF-β, NF-κB), yet they are still in the experimental stage.

3. Understanding and Prevention of LVNC in Traditional Chinese Medicine

3.1 Disease Classification, Etiology, and Pathogenesis

LVNC falls within the scope of "chest obstruction" or "heart failure" in TCM. Its etiology and pathogenesis are characterized by a combination of deficient root and excessive branch, with mixture of deficiency and excess. The primary factor of deficiency in origin is congenital insufficiency, as described in the Lingshu·Tiannian: "Human life begins… with the mother as the foundation and the father as the scaffolding." If parental essence and blood are deficient, the offspring will inherently have weak heart qi—a concept highly consistent with modern medical understanding of heredity. Weak heart qi and inadequate propulsion lead to poor blood circulation. Chronic illness affects the kidneys, resulting in heart-kidney yang deficiency, which impairs the warming and evaporating functions of body fluids, leading to internal water fluid. If yang deficiency further damages yin, a pattern of dual deficiency of qi and yin may emerge. The main pathological products of excess in manifestation are blood stasis, water fluid, and phlegm turbidity. Qi deficiency failing to propel blood, and yang deficiency causing cold congealing in the vessels, can both lead to internal blockage of blood stasis. Yang deficiency failing to transform fluids results in internal dampness retention; if this fluid ascends to harass the heart and lungs, it causes panting, and if it overflows to the skin, it causes edema. Dampness accumulating into water fluid together, further obstructs qi movement, making the condition protracted and refractory. The core pathogenesis of LVNC can be summarized as yang qi deficiency and decline, with blood stasis and fluid retention. Yang deficiency of the heart, kidney, and spleen constitutes the root, while blood stasis and water fluid are the branch. These factors interact causally, forming a vicious cycle.

3.2 Pattern Differentiation-Based Treatment

Based on the principle of "treatment based on pattern differentiation" and clinical practice, the common patterns and corresponding therapeutic approaches, formulas, and medicinals for LVNC are as shown in Table 2:

Table 2: Common TCM Patterns and Treatment Plans for LVNC

Pattern	Main Clinical Manifestations	Treatment Principle	Representative Formula	Commonly Used Chinese Medicinals
Qi deficiency and blood stasis	Shortness of breath, fatigue, palpitations, chest pain, pale purplish tongue	Boost qi, activate blood, transform stasis, unblock collaterals	Buyang Huanwu Decoction	Astragali Radix (Huangqi), Angelicae Sinensis Radix (Danggui), Chuanxiong Rhizoma (Chuanxiong), Persicae Semen (Taoren), Carthami Flos (Honghua)
Yang Deficiency and Water Flooding	Aversion to cold, cold limbs, edema, panting, scanty urine	Warm yang, promote diuresis	Zhenwu Decoction combined with Wuling Powder	Aconiti Lateralis Radix Praeparata (Fuzi), Poria (Fuling), Atractylodis Macrocephalae Rhizoma (Baizhu), Cinnamomi Ramulus (Guizhi), Alismatis Rhizoma (Zexie)
Heart-Kidney Yang Deficiency	Soreness and weakness of the lumbar and knees, cold body and limbs, worsening panting upon exertion	Warm and tonify the heart and kidney	Shenfu Decoction combined with Yougui Pill	Ginseng Radix et Rhizoma (Renshen), Aconiti Lateralis Radix Praeparata (Fuzi), Cinnamomi Cortex (Rougui), Rehmanniae Radix Praeparata (Shudihuang), Eucommiae Cortex (Duzhong)
Yang Collapse and Yin Exhaustion	Profuse sweating, cold limbs reaching the elbows and knees, faint pulse on the verge of extinction	Restore yang, secure desertion	Shenfu Longmu Jiuni Decoction	Ginseng Radix et Rhizoma (Renshen), Aconiti Lateralis Radix Praeparata (Fuzi), Mastodi Ossis Fossilia (Longgu), Ostreae Concha (Muli), Corni Fructus (Shanzhuyu)

3.3 Supporting Evidence from Modern Pharmacological Research on Chinese Medicinals

Modern pharmacological research provides a scientific basis for the treatment of LVNC with Traditional Chinese Medicine. Numerous studies have shown that active ingredients in Chinese medicinals can improve cardiac function, inhibit myocardial fibrosis, and regulate energy metabolism through multiple pathways.

Qi-Tonifying Medicinals (e.g., Astragali Radix [Huangqi], Ginseng Radix et Rhizoma [Renshen]): Primary active constituents such as astragaloside IV and ginsenoside Rg3 can enhance myocardial contractility, improve myocardial energy metabolism (by activating the PPAR-α pathway), inhibit cardiomyocyte apoptosis (by modulating the Bcl-2/Bax ratio), and reduce oxidative stress damage (by scavenging ROS) [14,15]. Research indicates that a bionic co-assembled nanodrug delivery system composed of the astragaloside IV derivative LS102 and Z-ligustilide can target damaged myocardium and significantly ameliorate myocardial fibrosis.

Yang-Warming Medicinals (e.g., Aconiti Lateralis Radix Praeparata [Fuzi], Cinnamomi Cortex [Rougui]): Higenamine from Aconite has cardiotonic and vasodilatory effects [16]; cinnamaldehyde can improve blood circulation and counteract myocardial ischemia.

Blood-Activating and Stasis-Resolving Medicinals (e.g., Salviae Miltiorrhizae Radix et Rhizoma [Danshen], Chuanxiong Rhizoma [Chuanxiong]): Components such as tanshinone IIA and tetramethylpyrazine possess antioxidant, anti-fibrotic (by inhibiting the TGF-β1/Smad pathway), microcirculation-improving, and anti-platelet aggregation effects. A study found [17] that Salvia miltiorrhiza extract can reduce the release of inflammatory factors like IL-1β and IL-18 and alleviate myocardial tissue inflammatory damage by inhibiting NLRP3 inflammasome activation.

Dampness-Percolating and Diuresis-Promoting Medicinals (e.g., Poria [Fuling], Alismatis Rhizoma [Zexie]): Pachyman (Poria polysaccharide) and alisol can promote diuresis and reduce edema, thereby diminishing cardiac preload, while also exhibiting certain anti-inflammatory and immunomodulatory effects [18].

3.4 Integrated Chinese and Western Medicine Prevention and Treatment Strategies and Advantages

The integrated Chinese and Western medicine approach to treating LVNC adheres to the principle of "disease-pattern combination and advantage complementarity". Based on

standard Western medical treatment, it incorporates TCM pattern differentiation and treatment, which can significantly enhance therapeutic efficacy [19].

Firstly, the integration can produce synergistic effects. Chinese medicinals can alleviate the side effects of Western drugs (e.g., electrolyte disturbances caused by diuretics), improve patient symptoms (e.g., fatigue, poor appetite), and enhance quality of life. Staged intervention based on TCM theory is applied: (1) Early Stage (asymptomatic or mild symptoms): Focus on boosting qi and nourishing yin, and activating blood and resolving stasis (e.g., using Shengmai San combined with Xuefu Zhuyu Decoction) to delay myocardial remodeling. (2) Middle Stage (significantly reduced cardiac function): Focus on warming yang and promoting diuresis, and activating blood and resolving stasis (e.g., using Zhenwu Decoction combined with Xuefu Zhuyu Decoction) to control heart failure symptoms. (3) Late Stage (end-stage heart failure): Focus on restoring yang and securing desertion (e.g., using Shenfu Injection) to stabilize vital signs and buy time for device therapy or transplantation.

The concept of "preventive treatment" is fully utilized. For gene carriers or asymptomatic patients, TCM is used to regulate constitution (e.g., by boosting qi and fortifying the spleen, or supplementing the kidney and filling the essence) aiming to "prevent disease before it arises and prevent progression after it arises".

4. Discussion and Prospects

This study provides a systematic review of the research progress and prevention/treatment strategies for LVNC in both traditional Chinese and Western medicine. Modern medicine has made significant advances in the genetic diagnosis, imaging assessment, and device therapy for LVNC, yet it still faces challenges in reversing the abnormal myocardial structure. Traditional Chinese Medicine (TCM), based on holistic regulation and treatment according to pattern differentiation, demonstrates unique advantages in alleviating symptoms, improving quality of life, and delaying disease progression through multi-component, multi-target interventions. Specifically, methods such as boosting qi and warming yang and activating blood and promoting diuresis have shown promising efficacy [19].

Current research exhibits the following limitations and future directions. Firstly, mechanistic exploration requires depth: The specific molecular mechanisms of TCM in preventing and treating LVNC (e.g., how it regulates emerging targets like METTL14 and RBMS1) remain unclear. Future research should integrate multi-omics technologies and gene-editing techniques to deeply explore the targets and pathways of compound Chinese herbal formulas. Secondly, clinical evidence needs strengthening: Existing TCM studies primarily consist of case reports or small-sample observations, lacking high-quality randomized controlled trials (RCTs). Future work should conduct multicenter, large-sample RCTs utilizing multi-dimensional indicators—such as cardiac function, quality of life, and biomarkers—to validate the efficacy of TCM.

Furthermore, innovation in Chinese medicinal formulations can be enhanced. Guided by the "theory-clinical practice-new drug development-experimentation-evidence-based medicine" integration model from the theory of collateral disease, innovative Chinese medicinals for LVNC (e.g., a series of formulas for boosting qi and activating blood) should be developed. Utilizing nanotechnology to improve drug delivery systems (e.g., bionic co-assembled nanoparticles for Chinese medicinals) can enhance targeting and bioavailability. Promoting deeper integration of Chinese and Western medicine is also an essential path. Exploring integrated treatment paradigms that combine Chinese medicinals with Western "pharmacological-technical" approaches, such as the synergistic mechanisms between Chinese medicinals and Guideline-Directed Medical Therapy (GDMT) or device therapy, is crucial. This effort should aim to establish integrated Chinese-Western medicine diagnostic and treatment guidelines and clinical pathways for LVNC.

In conclusion, the integration of Chinese and Western medicine offers novel ideas and paradigms for the prevention and treatment of LVNC. Combining the precise diagnosis and life support capabilities of modern medicine with the holistic regulation and symptom improvement offered by TCM holds the potential to provide patients with superior diagnostic and therapeutic experiences and clinical outcomes.

References

[1] Wang J, Kong X, Han P, et al. Combination of mitochondrial myopathy and biventricular hypertrabeculation/noncompaction. Neuromuscul Disord. 2016 Feb; 26(2): 165-169.

[2] Grecke BJ, Engberding R. Noncompaction Cardiomyopathy-History and Current Knowledge for Clinical Practice. J Clin Med. 2021 Jun 1;10(11):2457.

[3] Schweizer PA, Schröter J, Greiner S, et al. The symptom complex of familial sinus node dysfunction and myocardial noncompaction is associated with mutations in the HCN4 channel. J Am Coll Cardiol. 2014 Aug 26;64(8):757-767.

[4] Arbustini E, Weidemann F, Hall JL. Left ventricular noncompaction: a distinct cardiomyopathy or a trait shared by different cardiac diseases? J Am Coll Cardiol. 2014 Oct 28;64(17):1840-1850.

[5] Toader D, Paraschiv A, Tudorașcu P, et al. Left ventricular noncompaction-a rare cause of triad: heart failure, ventricular arrhythmias, and systemic embolic events: a case report. J Med Case Rep. 2021 Jun 8; 15(1):316.

[6] Chimenti C, Lavalle C, Magnocavallo M, et al. A proposed strategy for anticoagulation therapy in noncompaction cardiomyopathy. ESC Heart Fail. 2022 Feb; 9(1): 241-250.

[7] Bhatia NL, Tajik AJ, Wilansky S, et al. Isolated noncompaction of the left ventricular myocardium in adults: a systematic overview. J Card Fail. 2011 Sep; 17(9): 771-778.

[8] Sanna GD, Piga A, Parodi G, et al. The Electrocardiogram in the Diagnosis and Management of Patients with Left Ventricular Non-Compaction. Curr Heart Fail Rep. 2022 Dec;19(6):476-490.

[9] Jenni R, Oechslin E, Schneider J, et al. Echocardiographic and pathoanatomical characteristics

of isolated left ventricular non-compaction: a step towards classification as a distinct cardiomyopathy. Heart. 2001 Dec;86(6):666-671.
[10] Engberding R, Yelbuz TM, Breithardt G. Isolated noncompaction of the left ventricular myocardium -- a review of the literature two decades after the initial case description. Clin Res Cardiol. 2007 Jul;96(7):481-488.
[11] Srivastava S, Yavari M, Al-Abcha A, et al. Ventricular non-compaction review. Heart Fail Rev. 2022 Jul; 27(4): 1063-1076.
[12] Brieler J, Breeden MA, Tucker J. Cardiomyopathy: An Overview. Am Fam Physician. 2017 Nov 15; 96(10): 640-646.
[13] SONG Yin-yin, ZHANG Jing-wen, ZHAO Zi-nan, et al. Efficacy and safety of sacubitril/valsartan versus ACEI/ARB in heart failure with mid-range ejection fraction:a systematic review [J]. Chinese Journal of Hospital Pharmacy, 2022, 42(13): 1331-1339.
[14] Zhang LY, Yin HY, Song XZ, et al. Mechanisms of action of traditional Chinese medicine in the treatment of myocardial injury: A comprehensive review. Phytomedicine. 2025 Aug 23; 147: 157195.
[15] GUO Na, XUE Zizhuo, ZHANG Yanxin, et al. Pharmacological effects and mechanism research progress of traditional Chinese medicine invigorating qi preparations in improving myocardial fibrosis [J]. Drug Evaluation Research, 2025, 48(02):273-284.
[16] DIN Tao. Modern Pharmacology Theory Research and Clinical New-application of Aconitum Carmichaeli Debx [J]. Acta Chinese Medicine, 2012, 27(12): 1630-1631.
[17] ZHANG Rui, YAN Jingshun, JIA Fuyun, et al. Research progress on the improvement of myocardial fibrosis by traditional Chinese medicine through regulation of NLRP3 inflammasome [J]. China Pharmacy, 2025, 36(08): 1008-1012.
[18] LI Yiwei, WANG Jianguo. Literature Research on TCM Medication Rule of Coronary Heart Failure [J]. Chinese Journal of Ethnomedicine and Ethnopharmacy 2020, 29(22):16-19.
[19] KANG Yalong, NING Bo, TAN Juanjuan, et al. Analysis of Pattern Identification and Treatment of Left Ventricular Noncompaction (LVNC) Using the Method of Boosting Qi and Warming Yang [J]. Journal of Emergency in Traditional Chinese Medicine, 2024, 33(07): 1296-1298+1305.