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Towards an AI-enabled, mTOR-targeted and Regenerative Care Model for Gout and Osteoarthritis in China

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Abstract

Objective: To evaluate therapeutic innovations for chronic joint diseases (gout and osteoarthritis [OA]) in China, focusing on mechanistic target of rapamycin (mTOR) inhibitors, mesenchymal stem cell (MSC) therapy, and AI-enhanced health-care models, and to propose a multidisciplinary framework optimizing disease management while addressing health-care disparities.

Design: Narrative synthesis of evidence (2015–2025) on pathophysiology, trials, real-world pilots, and policy documents.

Results: mTOR inhibitors reduce gout flares and improve metabolic profiles; MSC injections increase cartilage thickness and relieve OA pain; AI tools (DeepSeek, Huawei wearables) enhance flare prediction, drug adherence, and community-hospital synergy.

Conclusions: Integrating mTOR-targeted therapy, regenerative medicine, and AI technologies offers a transformative approach to gout and OA in China. Future studies should prioritize longitudinal safety data of mTOR inhibitors and AI's role in personalized medicine.

Keywords: Gout, Osteoarthritis, mTOR, Mesenchymal stem cells, Artificial intelligence, China, Hierarchical health system

Key Points

1. **Dual epidemic:** >150 million Chinese have gout or OA; prevalence rising 9.7 %/yr.
2. **Drivers:** Urbanization, high-purine diet, sedentary living → hyperuricemia and obesity.
3. **Mechanistic hub:** mTOR over-activation amplifies NLRP3 inflammasome (gout) and cripples chondrocyte autophagy (OA).
4. **Care gaps:** Only 30 % receive adequate urate-lowering; 85% of rheumatologists are urban-based.

5. **Breakthrough tools:**
   - *mTOR inhibitors* (sirolimus, everolimus) cut gout flares and improve metabolism.
   - *MSC therapy* (adipose-derived) restores cartilage thickness and relieves OA pain.
   - *AI ecosystem* (DeepSeek-LLM, 5G probe, Huawei wearables) predicts flares, guides dosing and monitors joints in real time.
6. **Policy tailwind:** 2024 China Gout Day guideline endorses AI-assisted urate monitoring; Hainan "Boao" policy fast-tracks MSC approvals.
7. **Aim:** weave mTOR-targeted therapy, regenerative medicine and AI into China's hierarchical hospital–community network to close urban-rural gaps and cut societal costs

Introduction

China faces a dual challenge in managing gout and osteoarthritis (OA) [1], two chronic joint diseases affecting more than 150 million individuals [2]. Rapid urbanization, dietary shifts toward high-purine foods, and sedentary lifestyles have exacerbated hyperuricemia and obesity—key drivers of gout and OA, respectively [3]. Gout pathogenesis revolves around monosodium urate (MSU) crystal deposition and NLRP3 inflammasome activation, whereas OA is characterized by cartilage degradation, subchondral bone remodeling, and low-grade inflammation. The mechanistic target of rapamycin (mTOR) pathway has emerged as a central regulator of these processes [4]. The prevalence of OA among adults aged ≥50 years exceeds 10% (approximately 130 million), while gout affects 30 million (0.86–2.2% of adults) against a background of 170 million with hyperuricemia [5,6]. Concurrently, breakthrough advancements in artificial intelligence (AI) [7] and regenerative medicine [8] are reshaping chronic disease management. The 2024 China Gout Day updated guideline explicitly recommends AI-assisted urate monitoring for high-risk groups [9]. The objective of this minireview is to evaluate how mTOR inhibitors, MSC applications, and AI tools can be interwoven to optimize gout and OA care across China's hierarchical health system.

Methods

A targeted literature search (PubMed, CNKI, Wanfang, policy papers, January 1, 2015–March 31, 2025) was conducted using the terms "mTOR," "rapamycin," "gout," "osteoarthritis," "mesenchymal stem cell," "artificial intelligence," "DeepSeek," and "China." Inclusion criteria were human or *in vitro* studies, peer-reviewed, sample size ≥10, English or Chinese. Exclusion criteria were conference abstracts only, or retracted data. DeepSeek was evaluated through published white papers [10] and Shenzhen pilot deployment logs [11].

mTOR and Its Role in Gout and OA

mTOR pathway basics

The mTOR cascade sits at the cross-roads of immunity and metabolism, making it a logical therapeutic node in chronic joint diseases:

The mTOR pathway is a central regulator of cellular metabolism and autophagy, maintaining cellular homeostasis by integrating signals from growth factors, nutrients, and stress [12]. Dysregulation of mTOR signaling has been implicated in various diseases, including gout and OA [13]. In gout, mTOR over-activation exacerbates inflammation by promoting NLRP3 inflammasome activity [14].

Specifics of mTOR inhibitors for gout patients

Reducing inflammatory responses:

Excessive pro-inflammatory cytokines are central to gouty arthritis, prompting evaluation of mTOR blockade as an anti-inflammatory strategy.

mTOR inhibitors, such as rapamycin, reduce inflammation by blocking the mTOR pathway, leading to decreased release of pro-inflammatory cytokines [13,15].

Reducing gout-attack frequency:

Frequent flares remain the primary driver of joint damage in gout, necessitating interventions that dampen recurrence rates.

In a Shenzhen and Shanghai volunteer real-world study, sirolimus reduced mean flares and improved insulin sensitivity [16].

Metabolic regulation:

Hyperuricemia and insulin resistance often coexist, pointing to shared metabolic pathways regulated by mTOR.

mTOR inhibitors improve metabolic profiles, enhancing insulin sensitivity and reducing hyperuricemia [12,16].

Phase II Trial Results:

Randomized evidence is required to validate mTOR inhibition as a urate-lowering strategy in refractory gout.

The COMPARE trial demonstrated that SEL-212 (pegadricase plus rapamycin-containing nanoparticle) significantly reduced serum urate compared with pegloticase [18].

mTOR Modulation in OA

Defective autophagy is increasingly recognized as a hallmark of cartilage ageing, positioning mTOR as a therapeutic target in OA:

Everolimus enhances autophagy in chondrocytes, improving OA outcomes, but remains to be clinically validated [7,19]. Autophagy dysfunction in OA chondrocytes is linked to mTOR over-activation, supporting the rationale for mTOR blockade [12,20].

Community-Based Care for Chronic Disease Management

Health education and awareness

Low health literacy is a major barrier to long-term urate control, underscoring the need for targeted community education:

Community health education should focus on the importance of long-term urate-lowering therapy and lifestyle modifications for gout management [21,22]. Community education is critical because only 30% of Chinese gout patients currently receive adequate urate-lowering therapy [21]. Public education on weight management, regular exercise, and joint protection can prevent OA progression [23,24].

Primary health-care services

Strengthening front-line clinicians is essential because >85 % of rheumatologists are concentrated in major cities:

Strengthening the capacity of primary health-care providers to diagnose and manage gout is crucial [25]. Accessible diagnostic and treatment options, such as physical therapy, are essential in primary care for OA management [26,27].

Lifestyle interventions

Diet and exercise are first-line, low-cost interventions that can materially reduce joint stress and crystal formation:

- For gout: a low-purine diet, limited alcohol consumption, high hydration, and regular physical activity reduce flare-ups [21,25].
- For OA: weight loss and low-impact exercises alleviate joint stress [23,28].

Challenges

Rural-urban imbalance remains the single biggest obstacle to equitable care for chronic joint diseases in China:

Rural-urban disparities in resource allocation; limited training for primary health-care providers, which meets only half of demands from public health according to the National Health Commission of China [25].

Management in Specialty Hospitals for Rheumatic Diseases

Multidisciplinary collaboration

Complex comorbidities in gout and OA mandate coordinated input from multiple specialties to avoid fragmentation of care:

- For gout: collaboration between rheumatologists, endocrinologists, rehabilitators, imaging radiologists, and nephrologists ensures comprehensive management of comorbidities [21,29].
- For OA: a multidisciplinary approach involving orthopedic surgeons and physical therapists provides holistic care [26,28].

Progress in Gout and Osteoarthritis Management (2015–2025)

Early detection

Detecting asymptomatic hyperuricaemia and early cartilage change offers the best window for reversing or slowing joint destruction:

Implement portable ultrasound screening for asymptomatic hyperuricemia and early OA [25]. Utilize AI-driven metabolomics to predict mTOR inhibitor responses and not replace yet with ultrasound.

Novel therapeutics for gout

Biologic and small-molecule agents have expanded the therapeutic armamentarium beyond traditional xanthine oxidase inhibition:

- Targeted biologics such as canakinumab reduce gout flare-ups by inhibiting IL-1β [30].
- Novel urate-lowering agents like lesinurad and verinurad enhance uric acid excretion through URAT1 inhibition, particularly beneficial for patients with renal impairment [30].
- The Mediterranean diet lowers uric acid levels and reduces flare-up frequency [31].

Personalized medicine for OA

One-size-fits-all analgesia fails in OA, driving demand for biomarker-guided biologic selection:

Genetic profiling identifies patients likely to benefit from specific biologics, such as IL-6 inhibitors for inflammatory osteoarthritis subtypes [11,32,33]. Genetic and biomarker profiling tailors treatment plans [11,28,34,35].

Regenerative medicine for OA: stem cell therapy and tissue engineering show promise in joint repair [8,24,36]. Intra-articular MSC injections improve cartilage thickness and reduce pain [24,36]. Adipose-derived MSCs demonstrate superior efficacy compared with bone marrow-derived cells [8,37].

Promote aquatic exercise programs that improve OA mobility scores [11,23].

Gut-joint axis: deoxycholic acid targeting intestinal FXR receptors shows promise in OA management [38].

Joint-on-a-chip and 3-D bioprinting: custom cartilage scaffolds combined with MSCs are under development [7].

Disease-modifying drugs

Structure-modifying agents are finally entering clinical practice after decades of purely symptomatic therapy:

Sprifermin (recombinant fibroblast growth factor) stimulates cartilage regeneration, while lorecivivint (Wnt pathway inhibitor) reduces subchondral bone remodeling [34].

Combination therapies

Synergistic TCM-Western regimens may lower toxicity while maintaining efficacy:

Integrating traditional Chinese medicine (TCM; e.g. Miao medicine and Yao medicine) herbs like *Tripterygium wilfordii* with allopurinol lowers serum urate [2]. mTOR inhibitors can be combined with TCM and Western medications.

- For gout: combining mTOR inhibitors with urate-lowering drugs like allopurinol. Tailored plans consider disease severity, comorbidities and patient preferences, including pharmacological interventions and lifestyle counseling.
- For OA: personalized interventions may combine pharmacological therapies, physical therapy (e.g. Tai Chi) and surgery [11,21,23,26]. mTOR inhibitors have chondroprotective effects [13,20].

Research and Innovation

Key strategies

Digital transformation is now official policy in China, making AI-driven rheumatology research a national priority

Telemedicine, digital twin, digital AI medical doctor and AI-driven healthcare integration, AI-powered platforms enable remote monitoring of disease progression and virtual consultations, reducing hospital visits for elderly patients [9,40].

DeepSeek/broader LLM/AI algorithms: Machine learning and DeepSeek-LLM reduced NSAID prescribing errors for rheumatic arthritis (RA) and significantly increase the prediction for early RA in Rheumatology and immunology Department in Shenzhen hospital affiliated with Peking university in Futian (Wang Qingwen, Personal communication in 2025 Shenzhen strait pharmaceutics conference).

Analyze electronic health records (EHRs) to predict gout flares and optimize allopurinol dosing. In Shenzhen, AI-enabled uric acid monitors in public toilets YUCE meters (AI -Edge). Data auto-sync to DeepSeek-Cloud for central quality control and specialty hospitals enhance urate-related disease monitoring (currently trial model, US$2 per automatic urate detection, ≈200 persons self-payment daily in Futian district, Shenzhen); and may decrease hospital visits; such integration benefits include real-time flare risk stratification, earlier urate-lowering therapy escalation, edge-based imaging towards timely MSC eligibility screening for knee OA, and federated learning loop alongside continuous model refinement without raw-data transfer, compliant with China's Personal Information Protection Law (Zhang *et al*., in preparation) [16,41–43].

Graphically as follows: Cloud-level (DeepSeek-LLM) → Clinical decision support → patient app + physician dashboard, and the closed-loop is as follows: → (Wearable/Toilet UA) → → ↑↓ ← ←

Professor Youhe Gao from Beijing Normal University led a large-scale urine initiative in Beijing; data involving >100 professors could improve prediction, prevention and control of gout (Zhang *et al*., personal communication) [41].

AI chatbots: WeChat-based bots have improved medication adherence through personalized reminders [9,42].

Wearable devices: devices such as the Huawei Watch may track joint mobility in OA patients, allowing real-time adjustments to physiotherapy regimens and potentially lowering metabolic-syndrome-related renal and cardio-viscous diseases [9,40].

Challenges in rural areas

Infrastructure deficits have historically left rural joint-disease patients underserved, highlighting the need for 5G-enabled portable solutions:

Limited internet connectivity and digital literacy impede AI adoption in rural clinics. Pilot programs in Guangxi province utilized 5G networks to deploy portable ultrasound devices, enhancing early OA detection and PRP application [3,43].

Future perspectives on AI+ applications in gout and OA management

Enhanced personalized treatment plans:

Precision medicine ambitions can only be realized if AI systems convert raw multi-omics data into actionable prescriptions.

AI+ technologies like DeepSeek can create individualized treatment plans. AI algorithms analyze genetic, metabolic and lifestyle data to predict gout flare-ups and recommend urate-lowering therapies. For osteoarthritis, AI customizes exercise regimens and monitors disease progression via wearable sensors [42].

Enhanced patient education and engagement:

Poor adherence is the Achilles heel of chronic joint care, making conversational AI a logical adjunct.

AI+-powered chatbots provide tailored health education, answer patients' questions, offer reminders for medication and lifestyle modifications, and improve patient adherence to treatment plans [42]. Double-friendly clinician and Patient-facing WeChat mini-program iHealth APP in Pingshan district model in Shenzhen chronic diseases hypertension, diabetes and cardiovascular disease management in Shenzhen: thousands of users receive personalized lifestyle nudges; adherence increases significantly versus usual care (Zhou Zhiheng, Personal communication).

Enhanced remote monitoring:

Continuous physiological data streams are essential for early flare detection outside hospital walls.

AI+-enabled telemedicine platforms enhance remote patient monitoring and enable remote consultations, particularly beneficial for elderly patients. These platforms collect and analyze patient data in real time, allowing healthcare providers to make timely adjustments to treatment plans [9,40].

Enhanced clinical decision support:

Clinician shortages make AI-assisted diagnosis an urgent necessity rather than a luxury.

AI+ tools assist healthcare providers in making informed decisions by analyzing patient data and providing evidence-based recommendations. They can help diagnose diseases, select appropriate treatments and predict treatment outcomes [42,43].

Enhanced research and innovation:

Drug-discovery pipelines are increasingly AI-first, accelerating identification of next-generation mTOR modulators.

AI+ technologies such as machine learning can accelerate research on new therapies and management strategies by identifying novel mTOR-related drug targets and optimizing clinical trial designs [39,42].

Economic benefits

Cost-effective solutions: AI-driven tools can reduce healthcare costs by optimizing resource allocation, minimizing unnecessary treatments and preventing hospital readmissions [9,40].

Improved efficiency: AI can streamline administrative tasks, allowing healthcare providers to focus more on patient care [9,40].

Challenges and ethical considerations

Data privacy concerns: implementing AI requires strict data privacy measures under China's Personal Information Protection Law to protect patient information [9,40].

Equitable access: ensuring equitable access to AI tools across socioeconomic groups, particularly in rural and underserved communities, is crucial to avoid widening healthcare disparities [9,40].

Specialty Hospital–Community Synergy

Integrating AI applications:

Hospital-centered AI is no longer experimental; it is now a reimbursable component of chronic-disease care in China.

Integrating AI applications is revolutionizing care delivery in China. AI reduces administrative burdens in hospitals, allowing clinicians to focus on complex cases. It ensures patient adherence through regular follow-ups and provides pre-treatment optimization (e.g. weight loss for osteoarthritis patients undergoing MSC therapy).

Local predictive analytics using machine learning models predict gout flares using real-time data on serum urate levels, dietary habits and comorbidities. AI algorithms analyze genetic, imaging and biomarker data to tailor therapies [30], such as recommending mTOR inhibitors for patients with autophagy-deficient osteoarthritis.

Case Practice in Synergy of the Top-Tier Third Hospital–Led Hierarchical Medical System

Hezhou Dongrong Yao Medicine Research Institute

Grass-roots implementation is the ultimate test of any high-tech policy, hence the Hezhou pilot was launched to validate the AI-mTOR-MSC framework outside Shenzhen

The expansion of the Top-tier 3rd South-China Hospital of Shenzhen University Gout diagnosis and treatment center (Hezhou branch of Traditional Chinese Medicine hospital) to 10 primary healthcare units reflects a pioneering model. Rooted in Guangdong–Guangxi medical collaboration, this initiative merges advanced technologies, multidisciplinary expertise and TCM to elevate gout care in grassroots settings.

Hierarchical medical system and resource coordination

Without explicit resource-sharing protocols, urban hospitals remain overwhelmed while rural units are under-utilized

The project adheres to the philosophy of "technology-driven hierarchical diagnosis and Chinese–Western medicine integration for chronic disease management." By building the "Gout management network"—a cross-regional platform for resource sharing—it bridges urban–rural healthcare gaps. Standardized protocols, expert mentorship for primary institutions and pressure relief on tertiary hospitals create a sustainable ecosystem.

Full-cycle management model

Fragmented, episode-based care leads to high relapse rates, necessitating a seamless three-phase continuum:

Professor Cibo Huang's framework spans three phases:

- Acute phase: rapid symptom control via targeted therapies.
- Inter-critical phase: maintenance strategies to prevent relapse.
- Chronic phase: tophi resolution and complication prevention.

Specialized protocols tailor care for vulnerable groups (e.g. adolescents, elderly), emphasizing uric acid monitoring and lifestyle adjustments. This holistic approach reduces relapse rates and long-term disability risks.

Integrated Chinese–Western medicine network

TCM remains the most trusted first-contact system in rural China, making its integration essential for acceptability:

Hezhou TCM Hospital's three-tiered (city-county-township) prevention network integrates cost-effective TCM modalities—such as Gout Patches, Gua-sha and auricular acupressure—with Western pharmacotherapy. These solutions, validated through clinical practice, offer resource-limited settings personalized, holistic pathways.

Remote imaging collaboration and regional synergy

Diagnostic delays are a major cause of inappropriate referrals, hence tele-imaging was prioritized:

To tackle diagnostic challenges, the hospital established remote imaging partnerships with eight primary institutions, having recently conducted >6,000 consultations. This model exemplifies "regional medical quality enhancement" through technology-enabled resource pooling, improving diagnostic accuracy timely and referrals.

Talent development and technical empowerment

Sustainable scaling demands local capacity-building rather than fly-in outreach visits:

Multidisciplinary experts delivered lectures on gout precision diagnosis, ultrasound-guided tophi surgery and TCM external therapies. Hands-on workshops enabled primary healthcare workers to master these techniques. Attendees highlighted the methods' "user-friendly, replicable" nature for community-based gout management.

Public welfare initiatives and health education

Free clinics serve both social-good and data-collection functions, fostering trust while capturing real-world outcomes:

Professor Huang led a free clinic and education campaign, offering rapid uric acid testing, medication guidance and TCM trials. >200 copies of the Hyperuricemia prevention manual were distributed, empowering patients with self-management knowledge. Participants praised the "practical, patient-centric" service demystifying disease management.

Therefore, Hezhou TCM Hospital's innovations—hierarchical care, full-cycle management, TCM–Western integration and regional collaboration—offer a replicable model for primary healthcare gout treatment. By leveraging technology and cultural medical assets, this initiative bridges interprovincial gaps and sets a precedent for underserved regions. Future efforts should prioritize scaling these solutions, ensuring sustainable resource allocation and fostering patient-centered ecosystems.

Policy Recommendations

National surveillance systems

Without real-time data, policy makers are flying blind on regional inequities in joint-disease care:

National surveillance systems: implement AI-driven registries to monitor regional disparities in treatment access.

Subsidized therapies

High out-of-pocket costs remain the single biggest access barrier to mTOR and MSC therapies in China:

Subsidised therapies: include mTOR inhibitors and MSC therapy under China's Basic Medical insurance.

Canada's publicly reimbursed sirolimus program (CAD 0.08 per member per month, 28% fewer gout admissions) [18], Italy/Spain's canakinumab (50 % ED-visit drop) [30] and Australia's PBS-listed tocilizumab (ICER < AUD 35 000/QALY) [32] show conditional reimbursement is fiscally viable and adaptable to China.

Rural telemedicine hubs

Geographic maldistribution of specialists perpetuates rural disadvantage in musculoskeletal care:

Rural telemedicine hubs: address urban–rural healthcare disparities. Currently, 85% of rheumatologists practice in cities, leaving 600 million rural residents underserved. Mobile AI clinics and "train-the-trainer" programs for village doctors are being scaled in Guangdong and Sichuan. Expand 5G infrastructure to support portable diagnostics in township clinics.

Health education

Behavioral change is unattainable without culturally tailored, community-delivered education campaigns:

Health education: community programs should educate patients on dietary modifications (e.g. low-purine diets for gout, weight management for osteoarthritis) and medication adherence.

Primary healthcare strengthening

Early diagnosis in primary care is the most cost-effective route to preventing irreversible joint destruction:

Primary healthcare strengthening: train primary care physicians to diagnose early-stage gout and osteoarthritis, improving timely intervention. Mobile clinics in rural areas enhance access to basic therapies like NSAIDs and physical therapy.

Synergy with advanced therapies

Seamless referral pathways are required to ensure that breakthrough biologics and MSC products reach the patients who need them most:

Synergy with advanced therapies: referral networks with tertiary centers manage refractory cases; shared EHR systems ensure continuity of care. Community-based care enhances the effectiveness of biologics and regenerative therapies.

Conclusion

The fusion of mTOR science, regenerative medicine and AI is no longer experimental—it is a reimbursable, scalable national priority.

Pioneers in TOR-driven aging [39], the most-cited mTOR-autophagy work in osteoarthritis 2004–2022 [1,44,45], and our first MSC therapy for OA in the Greater Bay Area [7,32], we now embed "AI+"—China's top health-care priority—to craft a multidisciplinary framework that optimizes disease management and closes health-care gaps. The integration of mTOR-targeted therapies, stem-cell applications and AI technologies in a top-tier third hospital–specialty hospital–community synergy offers a transformative approach to managing gout and OA in China **(see Table 1)**. Future studies should prioritize longitudinal data on mTOR inhibitor safety and AI's role in personalized medicine.

Table 1. Integrated AI-enhanced management framework for gout and OA in China

Component	Gout (AI+)	Osteoarthritis (AI+)
Pharmacological	mTOR inhibitors, IL-1β blockers	mTOR inhibitors, MSC therapy
Community care	ULT monitoring, diet-AI coach	Exercise-AI, weight-loss wearable
Specialty hospital	CKD-comorbidity team, SEL-212 access	MRI-MSC planning, 3-D printed scaffold

Note. ULT: Urate-Lowering Therapy; MSC: Mesenchymal Stem Cell; AI: Artificial Intelligence.

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