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Innovations in Geriatric Hip Fracture Management in China: A Systematic Review of Recent Advances

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Abstract **Review Article**

Background: With the intensification of population aging, hip fracture has emerged as a major public health concern jeopardizing the well-being of the elderly population. However, conventional diagnostic and therapeutic paradigms exhibit significant limitations, including disparities in medical resource allocation and inadequate postoperative rehabilitation infrastructure. This systematic review aims to synthesize innovative practices and evidence-based findings within China's hip fracture management landscape over the past five years, with a focus on treatment modalities, surgical advancements, and rehabilitation strategies. ***Methods:*** We conducted comprehensive searches across databases including CNKI, Wanfang Medical Network, Springer, and PubMed for clinical studies, technical reports, and epidemiological surveys published between 2020 and 2025. Twenty-one representative articles encompassing key themes such as Multidisciplinary Team collaboration, robotic-assisted surgery, novel biomaterials, and community-based rehabilitation were selected for critical analysis. ***Results:*** Current research demonstrates that novel diagnostic and therapeutic approaches have yielded substantial breakthroughs in managing geriatric hip fracture patients. The implementation of green channels integrated with the Multidisciplinary Team model has optimized perioperative management, reduced hospital stays, and lowered complication rates. The introduction of robotic-assisted platforms and three-dimensional printing technology has significantly decreased operative duration while enhancing diagnostic and therapeutic precision. Furthermore, the adoption of Enhanced Recovery After Surgery protocols and the development of regional medical networks are progressively enhancing functional recovery outcomes. ***Conclusion:*** Hip fracture management in China is advancing toward precision medicine and standardized care. Future endeavors should prioritize strengthening tiered healthcare delivery systems and establishing integrated life-cycle management models, ultimately aiming to improve patient quality of life and mitigate the societal burden associated with this condition.

Keywords: Geriatric Hip fracture; Multidisciplinary Team collaboration; Robotic-assisted surgery; Enhanced recovery after surgery; Precision medicine; Community-based rehabilitation.

INTRODUCTION

Hip fracture (HF), often termed the "terminal fracture of life," poses a significant threat to the elderly population, with reported 30-day postoperative mortality rates reaching 6%–12% [1, 2]. The *Guidelines for treatment and management of hip fractures in the elderly (2022 version)* indicate that while age-standardized HF incidence rates have exhibited a declining trend in recent years, the absolute number of cases continues to escalate due to population aging. Consequently, HF remains a leading cause of disability and mortality among older adults [1]. This condition predominantly affects elderly patients with multiple comorbidities (including dementia, heart failure, and chronic kidney disease), osteoporosis, and hypoalbuminemia factors that exponentially amplify surgical risks [2]. Conventional HF management models are further challenged by protracted treatment pathways, frequent surgical delays, suboptimal perioperative care, and inadequate postoperative rehabilitation outcomes [3].

In response, China has progressively addressed these limitations through the integration of multidisciplinary teams (MDT), intelligent surgical platforms, and community-based rehabilitation networks. This review systematically synthesizes key technological advances and model innovations in HF management, analyzes barriers to clinical translation, and establishes a theoretical foundation for developing personalized HF management systems aligned with China's healthcare landscape.

METHODS

Comprehensive literature searches were executed across PubMed, CNKI, and Wanfang databases to identify relevant Chinese- and English-language publications spanning 2020–2025. Search strategies incorporated the following key terms: hip fracture, multidisciplinary collaboration, robotic-assisted surgery, and postoperative rehabilitation. Eligible studies focused on Chinese hip fracture populations (encompassing femoral neck fractures, intertrochanteric fractures, periprosthetic fractures, and related subtypes) were screened and selected. The final analysis included randomized controlled trials (RCTs), cohort studies, technical notes, and consensus guidelines, while excluding secondary publications (e.g., reviews, commentaries), animal studies, and reports with incomplete datasets.

Development of MDT Models and Optimization of Treatment Pathways

Traditional fragmented care pathways frequently delay surgical interventions, consequently elevating complication risks and prolonging hospitalization [4]. This necessitates the implementation of integrated care models. The *Guidelines for treatment and management of hip fractures in the elderly (2022 version)* advocate establishing emergency green channels and standardized assessment protocols to expedite evaluation and hospitalization [1]. Parallel recommendations from the *Guidelines for management of geriatric femoral intertrochanteric fractures* endorse early surgery (≤48 hours) within MDT frameworks [5]. In 2022, Fan *et al.*, retrospectively evaluated the MDT co-management model in Chinese geriatric intertrochanteric fracture patients [6]. The study compared an MDT cohort (n=241; 2017–2019) from Peking University Third Hospital against a traditional orthopedic care (TOC) cohort (n=249; 2014–2016). The MDT protocol—led by orthopedic surgeons with integrated geriatricians, anesthesiologists, intensivists, and physiotherapists—provided coordinated care from admission through discharge. Results showed that the MDT group had significantly shorter time from admission to surgery (1.7±1.3 days vs. 2.4±1.5 days, P<0.001) and a higher rate of surgery within 48 hours (80.9% vs. 63.5%, P<0.001) compared to the traditional group. Additionally, the length of hospital stay was significantly reduced (4.0±2.5 days vs. 5.0±2.8 days, P<0.001), and the overall postoperative complication rate was markedly lower (25.3% vs. 44.2%, P<0.001). Notably, while this model significantly improved perioperative metrics, no significant differences were observed in in-hospital mortality (0.4% vs. 0.8%, P=0.582) or 30-day mortality (1.7% vs. 2.4%, P=0.557). This suggests MDT models primarily mitigate complications associated with surgical delays, whereas long-term survival benefits require validation through larger-scale studies. Corroborating evidence from Yang Minghui's team at Beijing Jishuitan Hospital confirmed MDT implementation significantly increased 48-hour surgery rates (P<0.001), reduced hospital stays, and lowered in-hospital and 1-year mortality risks [7]. Discrepancies in mortality outcomes across aforesaid studies may reflect variations in baseline characteristics (e.g., age, comorbidity burden), sample sizes, and follow-up durations.

Aligned with national initiatives, Gansu Provincial Third People's Hospital established a standardized MDT platform incorporating green channel protocols [8]. Their comparative study demonstrated significant reductions in preoperative waiting time, length of stay, and incidences of pressure ulcers and pulmonary infections in the MDT cohort versus conventional care. To recapitulate, the integrated green channel-MDT model optimizes surgical timeliness, shortens hospitalizations, and enhances resource utilization. By comprehensively managing comorbidities (e.g., coronary artery disease, stroke history), MDT frameworks mitigate perioperative risks and reduce complication-related mortality [6-8]. Nevertheless, current evidence predominantly originates from observational cohorts and small-scale investigations. Future research should prioritize rigorously designed multicenter randomized controlled trials to establish universal applicability.

Innovations in Surgical Techniques and Advances in Precision Medicine

Recent advancements in Proximal Femoral Bionic Nail (PFBN) systems have substantially improved outcomes for unstable intertrochanteric femoral fractures (IFF). Based on the triangular support theory, this dual-triangle biomechanical construct optimally redistributes proximal femoral stress [9]. Clinical data demonstrate operative durations ranging from 83.1±12.2 minutes (AO/OTA Type A2) to 105.0±12.9 minutes (Type A3) (P=0.02), with 1-year Harris Hip Scores averaging 82.6±4.6. Crucially, 87.5% of patients achieved unassisted ambulation without implant cut-out or screw breakage, confirming superior biomechanical stability versus conventional Proximal Femoral Nail Antirotation (PFNA) devices [10]. Concomitantly engineered 3D-printed patient-specific titanium alloy prosthetic composites (e.g., titanium mesh-prosthesis hybrid constructs) achieve precise morphological conformity with proximal femoral anatomy. The micro-architected porous topology (mean pore diameter 600μm, porosity 70%) substantially augments osseointegrative efficacy while exhibiting markedly reduced complication rates relative to conventional allograft-prosthetic composites (P<0.05) [11]. Collectively, synergistic material innovations and structural refinements afforded by 3D printing technology substantially enhance procedural precision and osseointegration kinetics in complex revision total hip arthroplasty, thereby facilitating paradigm-shifting advancements in patient-tailored reconstruction for critical bone defects and osteoporotic conditions.

Notwithstanding, the longitudinal biomechanical stability of these innovative composite systems necessitate rigorous validation via multi-center cohort investigations.

Robotic integration has revolutionized post-fracture reconstruction precision. Beijing Jishuitan Hospital pioneered the Mako robotic-assisted "ring-point-column" acetabular reconstruction technique [12], developing four high-fidelity intraoperative registration methods demonstrating 98.5% success rate and 0.38 mm mean spatial accuracy. Robotic-assisted reaming facilitated precision prosthesis placement, yielding median angular deviations of merely 1.0° in inclination and 0.0° in anteversion relative to preoperative planning, with concomitant successful reconstruction of the hip rotation center (COR). Longitudinal radiographic surveillance revealed no evidence of implant failure, establishing this modality as a sophisticated therapeutic approach for complex acetabular revision surgery.Chen *et al.,* further demonstrated Tianji Robotic System integration with anatomical Union Plate technology [13], enabling minimally invasive placement of posterior column and infra-acetabular screws via 3D planning and real-time guidance. Versus conventional freehand techniques, the robotic cohort achieved superior perfect screw placement (Lonstein grade 0: 96% vs. 75%, P=0.024), significantly reduced intraoperative fluoroscopy (17.1±4.9 vs. 45.4±4.9 exposures, P<0.001), shorter screw placement time (19.9±3.2 vs. 42.5±6.7 minutes, P<0.001), also decreased operative duration and blood loss (P<0.05). Robotic surgery coupled with advanced implants optimizes precision and safety in complex HF management, propelling the field toward personalized minimally invasive solutions. Although these benefits, substantial costs remain a barrier to widespread adoption in resource-limited settings.

Standardization and Personalization of Postoperative Rehabilitation Systems

Contemporary clinical guidelines uniformly emphasize that early postoperative rehabilitation is paramount for functional restoration in geriatric HF patients. Healthcare institutions should establish MDT to initiate preoperative conditioning based on physiological reserve, subsequently tailoring postoperative protocols according to surgical approach, pain dynamics, fall risk stratification, and muscular recovery trajectories. Rehabilitation should commence with muscle strengthening exercises—optimally initiated on postoperative day 1—progressing to long-term balance training and fall prevention programs to enhance ambulatory capacity and restore functional independence [1, 5, 14]. Crucially, weight-bearing can be safely initiated immediately following internal fixation without elevating implant failure risk, while concurrently reducing hospitalization duration and mortality [15]. These accelerated rehabilitation paradigms are underpinned by Enhanced Recovery After Surgery (ERAS) principles, which provide evidence-based frameworks directly influencing recovery kinetics and prognostic outcomes [14]. A recent retrospective cohort study including 203 geriatric HF patients demonstrated that the ERAS group had significantly lower postoperative VAS scores than the conventional group (3.68±1.12 vs 4.26±1.58, P=0.003). Follow-up results indicated that the ERAS group exhibited significantly higher Barthel Index scores compared to the conventional group(80.27±12.31 vs 75.05±15.27, P=0.008) [16]. These findings substantiate that standardized ERAS protocols—integrating multidisciplinary collaboration, minimally invasive techniques, comprehensive analgesia, and early mobilization—effectively mitigate postoperative pain and accelerate functional restitution.

Despite escalating geriatric HF incidence amid accelerated population aging, conventional models exhibit critical deficiencies in post-discharge rehabilitation continuity—a pivotal determinant of surgical outcomes. Consequently, a tripartite hospital-community-home rehabilitation continuum has emerged, consolidating resources for sustainable long-term management [17]. Zhang *et al.,* validated this model through an RCT [18]: the intervention group (n=30) receiving phased video feedback rehabilitation guidance showed significantly higher Harris (89.7) and Barthel (89.7) scores at 3-month follow-up versus control (P<0.05). Community physician hubs further demonstrated economic viability, maintaining mean daily costs below RMB25.3 through coordinated care—substantially below conventional rehabilitation expenses. The *Expert consensus on perioperative nursing of geriatric hip fractures (2023)* advocates equipping community centers with remote monitoring systems to optimize outcomes [14]. Such technology enables real-time biometric tracking, facilitating remote progress assessment and dynamic protocol adjustments. Current operational frameworks necessitate MDT leadership from tertiary institutions, resulting in disproportionately low coverage in primary care settings. Future system refinements should prioritize resource reallocation and capacity building to address this disparity.

Prevention and Public Health Strategies

Geriatric HF, representing one of the most severe osteoporotic fracture phenotypes, poses substantial public health challenges due to high mortality rates, significant disability burdens, and elevated secondary fracture risk (86% higher than initial fractures). The *Experts consensus on intergrated management of geriatric hip fracture and prevention of secondary fracture* designates first-time HF patients as the highest-risk cohort for subsequent fractures. Falls constitute the predominant etiological mechanism, with prior fall victims exhibiting 2-3-fold higher recurrence risk versus non-fallers. Consequently, systematic fall risk screening should commence at the earliest clinically appropriate juncture, supplemented by periodic

reassessments. Implementation of nurse-led Fracture Liaison Services (FLS) coordinating multidisciplinary interventions—including osteoporosis pharmacotherapy, personalized exercise protocols, and environmental modifications—demonstrably reduces fall-related refracture incidence [17]. Future initiatives warrant development of artificial intelligence (AI)-enhanced risk stratification systems to streamline assessments, augment community-based primary prevention capabilities, and explore innovative FLS reimbursement models.

The predictive utility of muscle density metrics for secondary fractures provides novel pathophysiological rationale for prioritizing sarcopenia screening. Wang *et al.*,'s prospective cohort study utilizing quantitative CT analysis established gluteus medius/minimus density as an independent predictor of secondary HF (HR=1.68, 95% CI: 1.20–2.35; P<0.01), outperforming femoral neck BMD (P>0.05). This implicates compromised skeletal muscle integrity as a critical mechanism underlying recurrent fractures [19]. According to the Global Leadership Initiative on Sarcopenia (GLIS), sarcopenia constitutes a progressive disorder characterized by diminished skeletal muscle mass and function [20]. Recently, epidemiological surveillance indicates global sarcopenia prevalence ranges from 10%–27% among older adults, with China demonstrating substantially higher rates (20.7%) versus Japan (9.9%). Analysis of 7,775 participants (≥45 years) in the China Health and Retirement Longitudinal Study (CHARLS) cohort confirmed 33% elevation in hip fracture risk among sarcopenic individuals (OR=1.33). During 9-year follow-up, fracture incidence was significantly higher in sarcopenic versus non-sarcopenic groups (7.17% vs. 3.75%; P<0.001) [21]. However, diagnostic heterogeneity persists across existing sarcopenia criteria [20]. Future frameworks should integrate quantitative muscle density assessment into FLS risk stratification protocols, combined with resistance training and nutritional optimization to establish comprehensive bone-muscle preventive paradigms targeting secondary fracture reduction.

Summary

Through continuous innovation and exploration, novel diagnostic and therapeutic approaches have achieved significant breakthroughs in preoperative assessment, perioperative management, surgical precision, and postoperative rehabilitation for geriatric HF patients. Current evidence demonstrates that the integration of expedited pathways with MDT models substantially reduces preoperative waiting times, shortens hospital stays, and lowers complication and mortality rates, yielding superior clinical outcomes for high-risk populations [6-8]. Furthermore, surgical innovations including the PFBN system have eliminated implant cut-out and screw failure; 3D-printed patient-specific implants enhance osseointegration efficiency; while robotic-assisted arthroplasty confines acetabular reconstruction errors to ≤1° with near-zero dislocation rates, advancing HF management toward personalized and minimally invasive paradigms [10-13]. ERAS-guided early weight-bearing combined with tripartite "hospital-community-home" rehabilitation significantly improves functional independence [1, 14, 16-18]. Finally, sarcopenia has been established as an independent predictor of secondary fractures, advocating for skeletal muscle mass screening as a cornerstone of primary prevention and implementation of integrated "bone-muscle" preventive strategies [19-21]. Collectively, these findings provide an evidence-based framework for optimizing geriatric HF care systems with profound clinical, policy, and public health implications.

Despite these advances, current research exhibits limitations: ① Most MDT investigations employ single-center designs with limited sample sizes, constraining generalizability; ② Emerging technologies (e.g., PFBN, robotic surgery) lack longitudinal efficacy data; ③ Heterogeneous sarcopenia diagnostic criteria predispose to diagnostic inaccuracies, impeding standardized management. This review thus delineates a paradigm shift from fragmented intervention toward comprehensive precision management in geriatric HF care, providing foundational scientific support for developing efficient and equitable prevention-treatment systems.

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