The cost-effectiveness of a co-managed care model for elderly hip fracture patients in China: a modelling study

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Summary

Background The clinical effectiveness of multidisciplinary co-managed care for hip fracture patients in China has been demonstrated in a multicenter non-randomized controlled study. This study aims to estimate the cost-effectiveness of the co-managed care.

Methods The study is based on a multicenter clinical trial (n = 2071) in China. We developed a state transition microsimulation model to estimate the cost-effectiveness of the co-managed care compared with usual care for hip fracture patients from healthcare system perspective. The costs incorporated into the model included hospitalization costs, post-discharge expenses, and secondary fracture therapy costs. Effectiveness was measured using quality-adjusted life years (QALYs). Costs and effects were discounted at 5% annually. A simulation cycle length of 1-year and a lifetime horizon were employed. The cost-effectiveness threshold was established at USD 37,118. To address uncertainties, one-way deterministic sensitivity analysis and probabilistic sensitivity analysis were conducted.

Findings In the base case analysis, the co-managed care group had a lifetime cost of USD 31,571 and achieved an effectiveness of 3.22 QALYs, whereas the usual care group incurred a cost of USD 27,878 and gained 2.85 QALYs. The incremental cost-effectiveness ratio was USD 9981 per QALY gained; thus the co-managed care model was cost-effective. The cost-effectiveness was sensitive to the age of having hip fractures and hospitalization costs in the intervention group.

Interpretation The co-managed care in hip fracture patients represents value for money, and should be scaled up and prioritized for funding in China.

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Research in context

Evidence before this study

To address the health consequences of osteoporotic fractures in the elderly population, many countries have implemented multidisciplinary co-managed care for osteoporotic fracture patients. Given the scarce healthcare resources, economic evaluations of co-managed care were performed in numerous developed countries, suggesting its cost-effectiveness and informing the prioritization of co-managed care in healthcare funding. However, the economic benefits of this intervention model have not been conclusive in China, a nation with the largest elderly population, limiting informed decision-making about the financial viability of co-managed care.

Added value of this study

Based on a recent multi-center non-randomized controlled trial of the co-managed care model for post-hip fracture patients in China, this study developed a state transition microsimulation model to conduct a cost-effectiveness analysis of co-managed care. From the healthcare system perspective, co-managed care incurred USD 3693 higher costs and gained 0.37 additional QALYs compared to usual care, resulting in an incremental cost-effectiveness ratio (ICER) of USD 9981. Considering the Chinese cost-effectiveness threshold, the co-managed care model proves highly cost-effective for hip fracture patients in China. Additionally, the lower ICER in the younger group of elderly people suggests better financial viability for implementation in this population.

Implications of all the available evidence

This is the first economic evaluation of the multi-center multidisciplinary co-managed care model for hip fracture patients in China. The demonstrated cost-effectiveness, coupled with the health benefits, highlights the potential for scaling up and prioritizing resource allocation in the Chinese setting.

Introduction

Many countries, both developing and developed, have recognized the significant health challenge posed by osteoporotic hip fractures among the elderly. It has been projected that the global incidence of hip fractures will triple, escalating from 1.26 million in 1990 to an anticipated 4.5 million in 2050.[1] Hip fractures not only contribute to about 3-fold mortality in patients but also lead to reduced health-related quality of life and daily functioning.[2] However, a more pressing yet often overlooked concern pertains to subsequent fractures that occur after the initial hip fracture. Surprisingly, nearly half of the patients experience a secondary fracture within five years following the initial incident.[3] Subsequent fractures are related to 1.91- to 2.99-fold increased mortality risk, and also significantly impaired patients' overall well-being.[3,4]

Since 1990, evidence-based interventions have been developed with the aim of reducing the risk of secondary fractures.[5] Various single strategies, such as continuous medication, early surgery, and collaborative care by multiple healthcare staff, have demonstrated significant effects.[6,7] Consequently, there has been a concerted effort to integrate these individual interventions into a unified program, offering comprehensive care for hip fracture patients.[8,9] Among these initiatives, a care model involving primary care providers, nurses, and specialists from different disciplines has emerged as particularly successful. This multidisciplinary care model encompasses pre-surgery assessment, osteoporosis treatment, timely surgery, and comorbidity therapy for hip fracture patients.[9]

Multidisciplinary services for hip fracture patients are primarily focused on "timely surgery", a factor consistently reported as significant in reducing post-fracture mortality and complications, and promoting improved recovery of mobility and independence.[10,11] Recognizing these benefits, several countries have endorsed the recommendation for timely surgery following osteoporotic hip fractures.[12–15] However, it is noteworthy that despite the official publication of a hip fracture treatment and management guideline in China, which highly recommends early hospitalization and timely surgery within 48 h of the fracture,[16] the implementation and quality of care for hip fracture patients remain suboptimal. In China, the time to surgery for hip fracture patients (ranging from 24.3 to 59.2 h) significantly exceeds that of other countries.[12] Another challenging issue is the great economic burden of post fracture treatment for healthcare system. For instance, the hospitalization costs for hip fracture in China was reported to reach USD 10,355, the highest among all osteoporotic fracture sites.[17] In China, the healthcare costs are co-paid by the health insurance and patients' out-of-pocket expenses. Taking Beijing as an example, around 85% of hospital treatment costs for hip fractures are covered by the basic medical insurance scheme while for urban and rural residents the insurance covers more than 75% of the medical costs.[18]

Between 2018 and 2020, a multi-center non-randomized controlled study was conducted in China to assess the effects of a co-managed care centered on timely surgery.[9] The study reported positive outcomes, noting that patients receiving co-managed care exhibited a higher proportion of osteoporosis assessments (99.9% vs. 60.6%, $p < 0.01$), increased utilization of rehabilitation services (99.1% vs. 3.9%, $p < 0.01$), reduced hospitalization time (6.1 days vs. 12.0 days, $p < 0.01$), and lower one-year mortality (hazard ratio 0.59, $p < 0.05$).[9]

Nevertheless, the implementation of co-managed care is not without costs. The provision of comprehensive services for patients comprising collaboration among multidisciplinary specialists and nurses, requires an increase in facilities and health manpower to meet the augmented workload.[19] While this care model has demonstrated superior effects, decision-makers must also ascertain value in the face of these costs. This economic evaluation will further inform decision-makers about the financial viability of co-managed care in comparison to current treatment strategies.

Methods

The co-managed care model

The cost effectiveness analysis was conducted alongside a multi-center quasi-experimental non-randomized study of an orthogeriatric co-managed care model, which was conducted in six Chinese hospitals.[9] Osteoporotic hip fracture patients admitted into these hospitals were recruited as participants. The co-managed care was performed in Jishuitan hospital, with patients receiving the co-managed care were identified as intervention group. Those admitted to the remaining five hospitals—Beijing Hospital, Anzhen Hospital, Beijing Changping District Hospital, Beijing Shunyi District Hospital and Beijing Liangxiang Hospital—receiving usual care provided by orthopedic surgeons in orthopedic wards, were classified as the control group. In the intervention group, participants received medical care from orthopedic surgeons, emergency department physicians, and anesthesiologists upon admission to the emergency department. Upon transfer to the orthogeriatric ward, the medical care was led by orthopedic surgeons and geriatricians. This team provided pre-surgery assessments, prevention of post-operative complications, and treatment for comorbidities. Additionally, nutritionists, physiotherapists, and nurses collaborated to deliver comprehensive joint care. All patients were followed up at one-month, four-month and one-year post admission. The details of the program design and its clinical effectiveness has been reported elsewhere.[8,9]

Model structure

A state transition microsimulation model was developed to evaluate the cost-effectiveness of the co-managed care model compared to usual care in China. The model structure is shown in Fig. 1. The model comprises two arms: the co-managed care model arm for the intervention group and usual care arm for the control group. Each arm consists of three states: "hip fracture,"

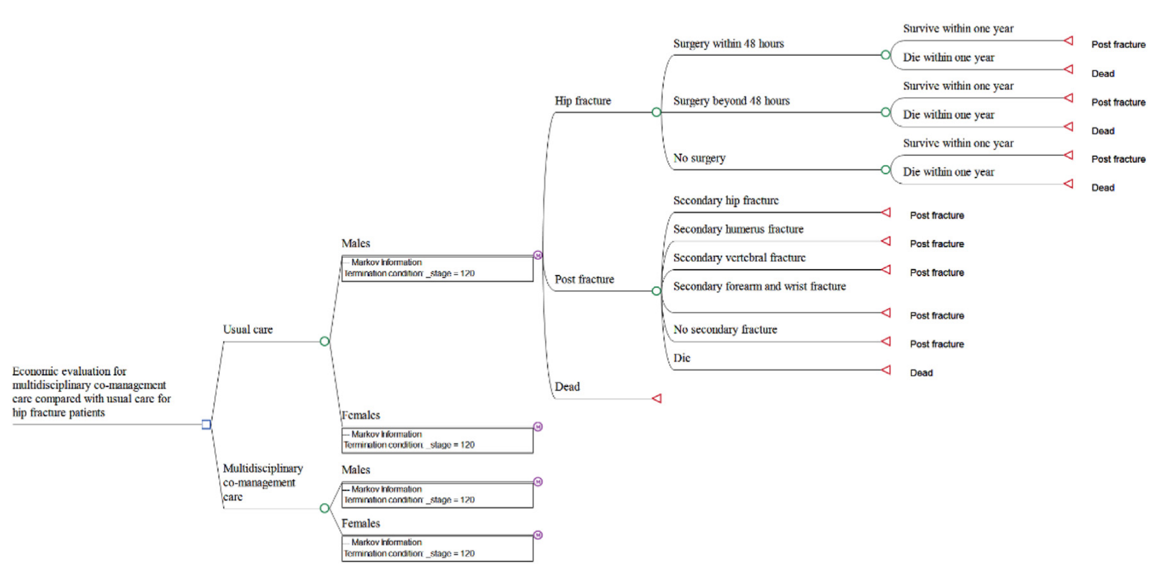

Fig. 1: **Structure of the cost-effectiveness analysis model for evaluation of the multidisciplinary co-management care compared with usual care for hip fracture patients.**

representing the status of all included patients upon entering the model; "post-fracture," covering the period between discharge and death; and "dead" as the absorbing state. Of note, the "post-fracture" state includes subsequent fracture occurrences, with four major osteoporotic fractures identified in this study: hip fracture, vertebral fracture, humerus fracture, and wrist and forearm fracture.

The Markovian model's memoryless property implies that the transition probability to the next state depends solely on the current state rather than any previous state.[20] However, since individuals have varying subsequent fracture risks and health utilities based on re-fracture sites and the timing of re-fractures,[2,4] we employed individual-level simulation, tracking patients' disease histories in this study. The cost-effectiveness analysis was conducted using TreeAge Pro 2019 (TreeAge Software, Williamstown, Massachusetts).

Simulated population

The population characteristics at the time of model entry aligned with those reported in the trial.[9] In particular, all individuals included in the model were hip fracture patients. In the intervention group, these patients were, on average, 79.7 ± 7.8 years old, with 72.1% being females, while those in the control group had an average age of 80.0 ± 7.4 years and a female proportion of 56.3%. Recognizing the significant variations in fracture risks and life expectancy between different sexes,[21] separate analyses were conducted for males and females. Of note, the cost-effectiveness of the treatment in our study was not based on the patients' body mass index as it was not captured from study participants in the clinical trial.

Transition probability

Patients in the model underwent transitions between different states, and the transition probabilities were derived from both the trial and existing literature.[2,4,9,17,20,22–31] The surgery rate for males and females in the co-managed care group was 98.7% and 98.3%, respectively, while in the control group, it was 87.5% for males and 90.8% for females ($p < 0.05$). Notably, in the intervention group, three-quarter of the patients (75.8% males and 75.1% females) underwent surgery within 48 h of admission, significantly higher compared to the control group (30.0% for males and 25.4% for females, $p < 0.05$).[9]

Sex-specific in-hospital mortality and one-year mortality after hip fractures in both groups were extracted from the trial. Subsequent-year mortality rates were estimated using the all-cause mortality rates in the Chinese general population, and modified by the age-adjusted mortality ratios following hip fractures.[4,32] The risk of secondary fractures at different sites faced by these patients was determined using Chinese-specific datasets[31] or international studies.[24,30] The increased mortality caused by re-fractures was estimated as the product of post-hip fracture mortality and the age-adjusted mortality hazard ratio of secondary fractures.[4] Following the guidelines of osteoporotic hip fracture treatment,[33] it was assumed that after discharge, all patients received weekly alendronate for osteoporosis treatment throughout their lifetime, leading to an average reduction in subsequent fracture risks by 30%.[23] In the base case analysis, an assumption of full treatment adherence was adopted and no side effects of the treatment was considered in the model.

Considering the disabilities and independence resulting from hip fractures,[29] it was further assumed that 20% of the patients needed long-term care.[25] All the rates were converted into risks as follows:

$$p = 1 - \exp(-rt)$$

where p represents the risks and r is the rates. t indicates the time and in this study it is one year ($t = 1$). Major parameters used in this study were listed in Table 1.[2,4,9,17,20,22–31]

Costs

The relevant costs associated with all states were sourced from published Chinese evidence. Specifically, the hospitalization costs for hip fracture treatment under both the co-managed care and usual care were derived from the trial.[20] There was no additional cost to set up an orthogeriatric ward as it used existing premises and facilities. Other resources utilization in the co-managed care model, including healthcare labor and time consumption, were incorporated into the overall patient hospitalization costs. The treatment costs for secondary fractures were extracted from a recent Chinese study.[17] Annual costs for weekly alendronate intake and long-term care after hip fractures were estimated at USD 784.62 and Renminbi (RMB) 28,440 yuan (USD 9550), respectively, based on data from the National Development and Reform Commission of China and several published Chinese studies.[27,35] All costs were then converted to 2023 US dollars using the two-stage computation adapting the consumer price index and the purchasing power parity.[36]

Effectiveness

Effectiveness was quantified using QALYs, a comprehensive health metric combining both the quality of life, measured by health state utilities (HSUs), and the length of life assessed through mortality, in this study. Age- and sex-specific HSUs in the Chinese general population were previously assessed in a comprehensive study and were integrated into our analysis as the baseline utility values.[28] The HSUs immediately following the hip fracture and that for the post-hip fracture period in the first year were estimated as the baseline HSUs multiplied by the disutility reported in

Variable	Point estimate (95% CI)	Distribution
HSU disutility for hip fracture, Point estimate (95% CI)[29]		
Immediately after hip fractures	0.31 (0.22–0.39)	Beta
1st year after hip fractures	0.776 (0.72–0.84)	Beta
Subsequent years after hip fractures	0.855 (0.80–0.91)	Beta
HSU disutility for other fracture sites, Point estimate (95% CI)[26]		
1st year after forearm and wrist fractures	0.97 (0.95–1.00)	Beta
1st year after vertebral fractures	0.89 (0.85–0.94)	Beta
1st year after humeral fractures	0.89 (0.85–0.92)	Beta
Treatment efficacy of alendronate, Point estimate (95% CI)[23]		
	0.7 (0.59–0.82)	
Costs for secondary fractures (USD 2016), Mean (SD)[17]		
Hip fracture	10,355 (7164)	
Vertebral fracture	5868 (6434)	
Forearm fracture	5740 (5048)	
Humerus fracture	6522 (5219)	
Annual Alendronate costs (USD 2020)[22]		
	784.62	
Annual care costs (RMB 2013)[27]		
	28,440	
Hospitalization costs for hip fracture patients (RMB 2020), Mean (95% CI)[20]		
FLS group	57,320 (17,058, 121,904)	
Control group	49,401 (10,569, 118,472)	
Relative risk of having a subsequent fracture, point estimate[2]		
Male	3.47	
Female	1.95	
Increased mortality hazard ratio after hip fractures, Point estimates (95% CI)[2]		
Male	3.51 (2.65–4.66)	
Female	2.43 (2.02–2.93)	
Increased mortality hazard ratio of secondary fractures, Point estimates (95% CI)[4]		
Male	2.74 (1.69–4.44)	
Female	1.99 (1.47–2.67)	
Patients' age, mean (SD)[9]		
FLS group	79.7 ± 7.8	Normal
Control group	80.0 ± 7.4	Normal
Proportion of female patients (%)[9]		
FLS group	72.1	
Control group	56.3	
Probability of needing care after hip fractures, point estimate[25]		
	0.2	
HSUs in general population, point estimate (95% CI)[28]		
Female	60–64 years: 0.893 (0.876, 0.911); 65–69 years: 0.889 (0.870, 0.908); 70–74 years: 0.858 (0.835, 0.881); 75–79 years: 0.855 (0.824, 0.887); 80–84 years: 0.811 (0.751, 0.872); 85+ years: 0.661 (0.522, 0.800)	Beta
Male	60–64 years: 0.88 (0.862, 0.897); 65–69 years: 0.869 (0.852, 0.885); 70–74 years: 0.827 (0.802, 0.851); 75–79 years: 0.808 (0.770, 0.846); 80–84 years: 0.746 (0.681, 0.811); 85+ years: 0.707 (0.561, 0.853)	Beta
Hip fracture incidence (annual rate per 1000 person-years)[31]		
Female	65–69 years: 0.96; 70–74 years: 2.34; 75–79 years: 4.08; 80–84 years: 6.44; 85–89 years: 6.59; 90+ years: 8.67	

(Table 1 continues on next page)

Variable	Point estimate (95% CI)	Distribution
(Continued from previous page)		
Male	65–69 years: 0.65; 70–74 years: 1.26 75–79 years: 2.37; 80–84 years: 5.19; 85–89 years: 5.71; 90+ years: 8.35	
Vertebral fracture incidence (annual rate per 1000 person-years)[24]		
Female	65–69 years: 5.64; 70–74 years: 8.74; 75–79 years: 12.05; 80–84 years: 21.19; 85+ years: 26.89	
Male	65–69 years: 0.95; 70–74 years: 2.26; 75–79 years: 4.5; 80–84 years: 5.94; 85+ years: 9.54	
Forearm and wrist fracture incidence (annual rate per 1000 person-years)[30]		
Female	65–69 years: 9.44; 70–74 years: 10.24; 75–79 years: 10.35; 80–84 years: 13.06; 85+ years: 14.38	
Male	65–69 years: 2.13; 70–74 years: 1.98; 75–79 years: 2.53; 80–84 years: 3.46; 85+ years: 5.18	
Humerus fracture incidence (annual rate per 1000 person-years)[30]		
Female	65–69 years: 2.85; 70–74 years: 3.62; 75–79 years: 5.95; 80–84 years: 6.67; 85+ years: 8.63	
Male	65–69 years: 1.12; 70–74 years: 1.98; 75–79 years: 2.13; 80–84 years: 1.91; 85+ years: 3.12	
All-cause mortality (per 1000)[20]		
Female	65–69 years: 13.06; 70–74 years: 24.36; 75–79 years: 40.89; 80–84 years: 73.98; 85–89 years: 115.29; 90–94 years: 180.24; 95–99 years: 219.46; 100+ years: 436.34	
Male	65–69 years: 21.26; 70–74 years: 37.02; 75–79 years: 59.13; 80–84 years: 98.56; 85–89 years: 146.53; 90–94 years: 211.66; 95–99 years: 212.07; 100+ years: 507.28	
Discount rate[34]	0.05 (0–0.08)	

HSUs, health state utilities; CI, confidence interval; SD, standard deviation; RMB, Renminbi yuan, the currency in China.

Table 1: **Key parameters derived from literature for base-case analysis.**[2,4,9,17,20,22–31]

China.[29] We assume that the HSUs immediately after hip fracture were the same in both groups. Health state disutility for subsequent years after hip fracture and for different re-fractures was sourced from relevant literature.[26,29] The model also incorporated patients' mortality after hip fractures. Specifically, in-hospital mortality and one-year outpatient mortality were sourced from the trial.[9] Mortality in the subsequent years was estimated using the product of all-cause mortality in the general population and the mortality hazard ratio after hip fractures extracted from relevant literature.[2] Additionally, the model further integrated the hazard ratio of mortality after secondary fractures.[4]

Cost-effectiveness analysis

The cost-effectiveness analysis was conducted for a simulated post-hip fracture population that mimic the characteristics of the trial participants. The analysis was performed from the perspective of healthcare system, employing a cycle length of one year and a lifetime horizon. In the base case analysis, and lifetime total costs and QALYs were simulated for both the patients from the co-managed care model and the usual care group. Based on the recommendation from the Guidelines for The Evaluation of Chinese Pharmacoeconomics 2020, all costs and health state utilities were discounted at an annual rate of 5%.[34] Based on the simulated lifetime costs and effectiveness, the incremental cost-effectiveness ratio (ICER) was calculated as the difference in costs divided by the difference in effectiveness between the co-managed care model and the usual care[37]:

$$ICER = \frac{Incremental\ Costs}{Incremental\ Effectiveness} = \frac{Costs_a - Costs_b}{Effectiveness_a - Effectiveness_b}$$

where the $Costs_a$ and $Effectiveness_a$ represent the lifetime costs and effectiveness of co-managed care while $Costs_b$ and $Effectiveness_b$ indicate the lifetime costs and effectiveness of usual care. Determination of cost-effectiveness for the co-managed care model utilized a cost-effectiveness threshold in China of RMB 128,000 (USD 37,118).[36,38] To explore the joint uncertainty of all parameter distributions, probabilistic sensitivity analysis was conducted. Distributions of variables in the model were resampled simultaneously in the probabilistic sensitivity analysis to address parameter uncertainty. In the base-case analysis, a total of 10 million simulations (5000 resampling × 2000 trials) were performed. Additionally, one-way deterministic sensitivity analysis was performed to assess the impact of individual model parameter values on cost-effectiveness. The reasonable ranges for key parameters were determined. Parameters included in the sensitivity analysis comprised the proportion of females (ranging 0–1), patient age (60, 70 and 80 years old respectively), baseline HSUs (0.8–1.2 times change), in-hospital mortality (0.5–1.5 times change), one-year mortality (0.5–1.5 times change), surgery rate, fracture risk (0.8–1.2 times change), costs related to the study (0.5–2 times change), the discount rate (ranging 0–0.08),[34] and adherence of anti-osteoporotic drugs (ranging 0–0.8). A cost-effectiveness acceptability curve for different cost-effectiveness thresholds was used to assess the probability that the co-managed care was cost-effective compared with usual care.

Model validation

The state transition microsimulation model was evaluated for face validity, verification and cross-validity following the guidelines of the International Society for Pharmacoeconomic and Outcomes Research and the Society for Medical Decision Making (ISPOR-SMDM) Modeling Good Research Practices Task Force-7.[39] Our model was developed referring to an existing validated model,[20] with more detailed statuses evaluated by a health economist (LS) and a clinician (MY). To improve the verification of the model, effects data from the original trial or evidence from a similar population or the same context were input to simulate the costs and effectiveness in the model. Finally, findings of cost-effectiveness were compared with other economic evaluation studies for post-hip fracture treatment and management in China, with possible reasons for the difference being further discussed.

Reporting quality

This study followed the recommendations for economic evaluation in osteoporosis developed by the European Society for Clinical and Economic Aspects of Osteoporosis, Osteoarthritis and Musculoskeletal Diseases (ESCEO) and the US branch of the International Osteoporosis Foundation.[40] The reporting of this study followed the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) 2022.[41] The reporting quality check is shown in Supplementary Material 1.

Role of the funding sources

The funders had not influenced the study design, data collection, model development, data analysis, interpretation, or writing of the manuscript.

Results

The model demonstrated good performance regarding face, internal and cross-validities. The simulated lifetime costs and effectiveness of co-managed care and usual care are presented in Table 2. On average, patients receiving co-managed care incurred an additional cost of USD 3693 but gained 0.37 additional QALYs compared

	Lifetime costs (USD)	Lifetime QALYs	Incremental costs (USD)	Incremental QALYs	ICER(USD)
Co-managed care	31,571.39	3.22	3693.05	0.37	9981
Usual care	27,878.34	2.85			

QALYs, quality-adjusted life years; ICER, incremental cost-effectiveness ratio.

Table 2: **Base case analysis of cost effectiveness of multidisciplinary co-managed care for hip fracture patients.**

to those in the usual care group. The ICER was calculated at USD 9981 per QALY gained. Given a cost-effectiveness threshold of USD 37,118 per QALY gained, the co-managed care program is deemed cost-effective.

The outcomes of the probabilistic sensitivity analysis are represented in the incremental cost-effectiveness scatter plot (Fig. 2) and the cost effectiveness acceptability curve (Supplementary Material 2). In all simulations, co-managed care exhibited higher effectiveness and costs, with the ICER ranged between USD 7058 and USD 16,191. The ICER was consistently below the defined cost-effectiveness threshold (USD 37,118), indicating a 100% probability that co-managed care was cost-effective under the current values and distributions of parameters.

The results of the one-way sensitivity analysis are presented in Table 3. The ICER of co-managed care was most sensitive to changes in patients' age and treatment costs. Specifically, the ICER for the younger population aged over 60 years was USD 6357 per QALY gained, which was lower than that for the older population aged over 70 years with an ICER of USD 9267 per QALY gained. Notably, co-managed care implemented in patients aged over 80 years was not considered cost-effective, with an ICER of USD 39,648 per QALY gained.

Furthermore, when the hospitalization costs of usual care decreased to 50%, co-managed care was no longer cost-effective with an ICER of USD 50,550 per QALY gained. Conversely, if the hospitalization costs doubled, the intervention became cost-saving. Assuming other variables remained constant, the co-managed care was cost-effective as long as the patients' hospitalization costs in the intervention group was lower than USD 45,157. Variations in other parameter values did not change the conclusion of the evaluation; the co-managed care program remained cost-effective.

Discussion

Based on a multi-center quasi-experimental non-randomized study of an orthogeriatric co-managed care model in China, this study reports the cost-effectiveness of this co-managed model. Patients in the co-managed care model group demonstrates an additional 0.37 QALYs at an increased cost of USD 3693 compared to usual care. Consequently, the co-managed care costs additional USD 9981 for every additional QALY gained, which means the co-managed care model is cost-effective in the Chinese setting. The cost-effectiveness of this model of care diminishes with the

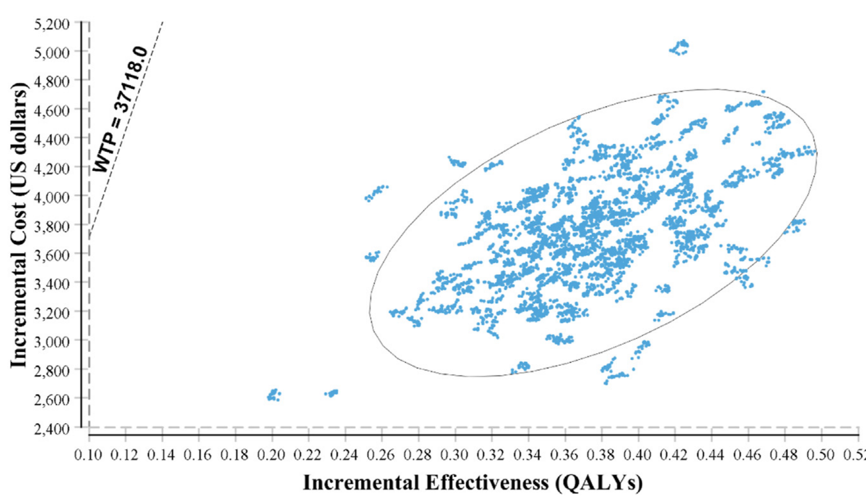

Fig. 2: **Results of probabilistic sensitivity analysis**. QALYs, quality-adjusted life years; WTP, willingness to pay. This incremental cost-effectiveness scatter plot presents the probabilities of co-management care being cost-effective compared with usual care. Every dot shows the incremental cost-effectiveness ratio for joint distributions of all parameter. Across all 5000 resampling iterations, all the dots fall below the WTP threshold line ($37,118 per QALY gained), representing that the co-management care has a probability of 100% to be cost-effective.

Variable	ICER (USD)
All males	9778
All females	10,636
Patients cohort starting age: 60 years	6357
Patients cohort starting age: 70 years	9267
Patients cohort starting age: 80 years	39,648
All patients in intervention group having surgery within 48 h	9843
0.5 times the hospitalization costs in control group	50,550
2 times the hospitalization costs in control group	Dominant
0.5 times the hospitalization costs in intervention group	Dominated
2 times the hospitalization costs in intervention group	25,666
0.5 times the hospitalization costs in both groups	Dominated
2 times the hospitalization costs in both groups	31,006
0.5 times the costs of treating secondary fractures	8838
2 times the costs of treating secondary fractures	10,628
0.8 times the base-case health state utility	11,793
1.2 times the base-case health state utility	7862
No discount rate	8141
Discount rate of 0.08	10,237
0.8 times the risk of having secondary fracture	9196
1.2 times the risk of having secondary fracture	9673
0.8 times mortality risk after hip fractures	9024
1.2 times mortality risk after hip fractures	9864
0.5 times in-hospital mortality for patients having surgery within 48 h in control group	9615
1.5 times in-hospital mortality for patients having surgery within 48 h in control group	9262
0.5 times in-hospital mortality for patients having surgery beyond 48 h in control group	9572
1.5 times in-hospital mortality for patients having surgery beyond 48 h in control group	9302
0.5 times in-hospital mortality for patients having surgery within 48 h in intervention group	9395
1.5 times in-hospital mortality for patients having surgery within 48 h in intervention group	9474
0.5 times discharge one-year mortality for patients having surgery within 48 h in control group	10,842
1.5 times discharge one-year mortality for patients having surgery within 48 h in control group	8400
0.5 times discharge one-year mortality for patients having surgery beyond 48 h in control group	13,572
1.5 times discharge one-year mortality for patients having surgery beyond 48 h in control group	7431
0.5 times discharge one-year mortality for patients having surgery within 48 h in intervention group	7683
1.5 times discharge one-year mortality for patients having surgery within 48 h in intervention group	12,645
0.5 times discharge one-year mortality for patients having surgery beyond 48 h in intervention group	8610
1.5 times discharge one-year mortality for patients having surgery beyond 48 h in intervention group	11,864
0.5 times one-year mortality for patients with no surgery in control group	10,978
1.5 times one-year mortality for patients with no surgery in control group	8329
0.5 times one-year mortality for patients with no surgery in intervention group	9356
1.5 times one-year mortality for patients with no surgery in intervention group	9515
Anti-osteoporotic drugs treatment adherence of 0	11,145
Anti-osteoporotic drugs treatment adherence of 0.2	10,729
Anti-osteoporotic drugs treatment adherence of 0.4	10,614
Anti-osteoporotic drugs treatment adherence of 0.6	10,561
Anti-osteoporotic drugs treatment adherence of 0.8	10,214

ICER, incremental cost-effectiveness ratio.

***Table 3*: Results of one-way sensitivity analysis.**

age of patients, with the threshold being around 80 years when the program becomes not cost-effective.

Despite having the largest elderly population globally, China has not adequately addressed the prevention of osteoporotic secondary fractures, posing a significant threat to elderly health. In China, only two published economic evaluation studies on re-fracture prevention strategies were identified, both demonstrating the cost-effectiveness of these interventions.[20,35] Peng et al. conducted an evaluation of a clinical trial involving multidisciplinary care, reporting an ICER of USD 19,437 for this intervention.[20] Meanwhile, Li et al. undertook a model-based economic assessment of a Fracture Liaison Service (FLS) using data extracted from the literature, determining that the FLS in China was cost-saving.[35] However, our cost-effectiveness analysis study represents notable differences across several aspects. First, our study employed detailed age- and sex-specific transition probabilities between different states in the model, and distinguished between different types of secondary fractures and assigned separate fracture risk values, offering a more comprehensive representation of the patient journey and enabling a more robust evaluation. Second, in contrast to the previous study using data from the literature, we incorporated data for both intervention and control group from a multicenter trial in China,[9] enhancing the relevance and applicability of our evaluation in health decision-making processes.

The cost-effectiveness of co-managed compares favorably with other pharmaceutical interventions for osteoporotic fracture prevention in the Chinese setting, such as zoledronate (ICER ranges between USD 7865 and USD 26,637),[42,43] alendronate (ICER= USD 13,235),[42] teriparatide (ICER= USD 36,891)[42] and raloxifene (ICER= USD 36,891).[44] These findings underscore that fundings for secondary fracture prevention should be prioritized.

The global adoption of combined hip fracture care involving various healthcare providers has gained prominence, with widespread assessments of their cost-effectiveness. Many of these strategies have demonstrated their financial viability in enhancing health outcomes and preventing subsequent fractures. For instance, in Canada, co-managed care for hip fracture patients cost CAD 6750 to achieve one perfectly healthy year,[45] while in Germany, a similar intervention required €52,378.[46] In England, multidisciplinary care, incorporating an orthogeriatrician, was identified as the most cost-effective approach to hip fracture treatment.[47] Due to its observed clinical and economic benefits, interprofessional collaboration has been involved in FLSs in many countries,[48] and was also incorporated as one of the official standards for best FLS, as developed by the International Osteoporosis Foundation.[49] The findings from this study indicating the cost-effectiveness of re-fracture prevention for hip fracture patients, not only contribute to informed decision-making in the allocation of osteoporosis resources in the Chinese context but support investment in osteoporosis multidisciplinary care globally.

Factors identified as influencing cost-effectiveness provide valuable information for refining the details in intervention design and implementation. In the sensitivity analysis in which the female proportion was adjusted between 0 (all patients were males) and 1 (all patients were females), the co-managed care remained cost-effective as the ICER was consistently lower than the cost-effectiveness threshold. Therefore, the cost-effectiveness of the intervention was robust with the patients' sex proportion change. The results were in line with previous Chinese studies.[20,35] However, patient age emerged as a crucial determinant affecting the cost-effectiveness of co-managed care. Notably, for the same financial investment, co-managed care implemented in a younger elderly population (aged over 60 years) resulted in more health benefits, measured by QALYs, compared to implementation in an older population group (aged over 70 or 80 years). This trend aligns with findings from previous economic evaluations of re-fracture prevention strategies.[20,35] Based on existing evidence, people experiencing hip fractures in China are typically younger compared to those in Europe and North America.[50,51] This highlights the crucial need to invest in co-managed care for hip fractures in China. Interestingly, this age-related correlation is not consistently observed in other osteoporosis interventions. For osteoporosis drugs, for instance, the ICER was more likely to be lower (more cost-effective) with increasing patient age.[44,52] Similarly, for hip protectors and osteoporosis screening, the ICER was found to be lower in older sub-groups,[53,54] suggesting these interventions were more cost-effective when implemented in older vs. younger populations. The difference in these trends can be explained by the nature of the interventions. Co-managed care, including services such as timely surgery, complication treatment, multidisciplinary specialists' care and rehabilitation, primarily demonstrates its main effects through reduced mortality after fracture.[9,20] In this context, the incremental QALYs are mainly attributed to the life years gained and thus more QALYs available to be gained for younger patients. Since our model did not distinguish hip fracture hospitalization costs by patient age, the younger elderly population receiving co-managed care had more QALYs and, consequently, a lower ICER. In contrast, for drug interventions, the clinical effects mainly focus on reducing fracture risk (often using dis-utilities).[55] Given that older populations have higher fracture (or re-fracture) risk,[24,31] the reduction in the quantity of fracture risks is also higher in older populations compared to younger ones. Not all economic evaluation studies report changes in ICER with patient age and thus further analysis of more interventions in different countries is necessary to measure the robustness of this correlation. Nevertheless, co-managed and long-term medication interventions benefit hip fracture patients in various domains, suggesting that a more comprehensive healthcare model combining in-hospital multidisciplinary care and long-term medication intervention, such as FLSs, might represent better health effects for hip fracture patients.

An interesting observation in the incremental cost-effectiveness scatter plot is the proximity of some points in distribution, indicating that certain iterations produced similar results. This phenomenon could be attributed to the parameter values and distributions input into the model. On one hand, point estimates of secondary fracture risks were utilized due to the absence of their distributions.[2,24,31] On the other hand, for certain parameters such as all-cause mortality, fracture risks, and health utility in the general population, only estimates for specific age groups (e.g., aged 70–74 years) were available and employed in the analysis.[20,28] The use of these parameters may lead to the outcome that, even with random re-sampling in probabilistic sensitivity analysis, the results are not uniformly distributed in the scatter plot. For individuals entering the model at the same age, there is a high likelihood that those following similar pathways would exhibit comparable health outcomes. The specific measurement of these parameters, along with their distribution, would contribute to more precise and varied results.

Despite the confirmed and robust cost-effectiveness of the co-managed care model, there are some recommendations to improve the broader implementation of this intervention in China. First, given the limited number of coordinator-based multidisciplinary care programs for fracture patients in China,[56] more attention should be paid to the post-hip fracture treatment and secondary fracture prevention. Second, the active involvement of key decision makers, including government officials and healthcare administrators, is required to ensure sufficient resource allocation and coordination across different sectors.[8] Moreover, it is recommended that professional training be provided to all healthcare professionals involved in the program, to enhance their collaboration skills and necessary health service qualifications.[8,57] Finally, our sensitivity analysis indicated that the intervention was still cost-effective even under a significant increase in the cost of setting up the co-managed program.

It is important to acknowledge the limitations of our study. First, several parameters in the study were indirectly determined. For example, patients' health utility values, mortality rates, and secondary fracture prevalence in subsequent years after hip fracture were not available in the trial and they were derived from literature. For parameters that are unavailable in the Chinese population, they were taken from international literature in other populations.[2,24,30] Moreover, some parameters only have point estimates, and therefore they were not included in the probabilistic sensitivity analysis. This might have limited the understanding of the uncertainties around the ICERs; however, we have conducted the extensive one-way sensitivity analyses to identify the parameters that might have significant impact on the cost-effectiveness results. Second, the economic evaluation was based on a non-randomized controlled trial, where the intervention was implemented in an urban tertiary hospital that had better infrastructure resources, while usual care was conducted in five urban and rural hospitals.[9] Bias could potentially arise due to the non-uniformity of medical service levels across different hospitals, variations in patient fracture severity, and the potential influence of patient preferences on hospital selection. Considering this limitation, we have conducted the one-way sensitivity analysis to evaluate the possible impact of change in the clinical effectiveness on the cost-effectiveness of the intervention. Nevertheless, future evaluations based on randomized clinical trials for co-managed care in hip fracture patients are needed to provide more accurate evidence. Finally, as the clinical data used for our study are from a trial conducted in one city, future studies on the cost-effectiveness of co-managed care for hip fracture patients in a more generalized population are necessary to ensure its potential for scaling up. The budget impact analysis is also recommended to provide more evidence for health decision making in osteoporotic fracture field.

Conclusion

Our study reveals that multidisciplinary co-managed care for hip fracture patients in the Chinese context is highly cost-effective, particularly in the younger elderly population. Coupled with the demonstrated health benefits, the positive cost-effectiveness findings provide valuable insights for policymakers, affirming the clinical and financial acceptability of including co-managed care in the priority list for resource allocation decisions in the field of osteoporosis.

Contributors

Conceptualization and Methodology: LS, SJ, MY and MT; Data collection: LX, MY, XZ, JZ, JH, LW, XW, ZS, SH, FS, ZG, MS, KP, PY, RM, XW, MC and RI; Model development: LS and LX; Data analysis: LX; Study supervision: LS; Data verification: LS. MT, JZ and LX had access to raw data. LX prepared the original draft. MT, MY, LX and LS had final responsibility for the decision to submit for publication. All authors reviewed, edited and approved the final manuscript.

Data sharing statement

Access to data could be available upon reasonable request to corresponding author MT.

Declaration of interests

LX, MY, XZ, JZ, JH, LW, XW, ZS, SH, FS, ZG, MS, KP, PY, RM, XW, MC, SJ, RI, MT and LS declare that they have no conflict of interest.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lanwpc.2024.101149.

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