


## CLINICAL ARTICLE

# Trends in Comorbidities and Postoperative Complications of Geriatric Hip Fracture Patients from 2000 to 2019: Results from a Hip Fracture Cohort in a Tertiary Hospital

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**Objective:** To describe the secular trends in comorbidities and postoperative complications of geriatric hip fracture patients from the Chinese People's Liberation Army General Hospital Hip Fracture Cohort between 2000 and 2019.

**Methods:** We included 2,805 hip fracture patients aged 65 years or older and received surgical treatment from 25 January 2000 to 19 December 2019. Demographic characteristics, comorbidities, postoperative complications, length of hospital stay, and the time to surgery were extracted and examined in each 5-year period based on the admission year, namely 2000–2004, 2005–2009, 2010–2014, and 2015–2019. Categorical data were analyzed by chi-squared or Fisher's exact test, with ordinal data by row mean scores difference test and continuous data by one-way analysis of variance. Trends in comorbidities and postoperative complications were examined by the Cochran–Armitage trend test.

**Results:** The average age of the included population was  $79.1 \pm 7.3$  years (mean  $\pm$  standard deviation), and 69.1% were female. From 2000 to 2019, the proportion of females increased from 59.8% to 73.0% ( $P$  for trend  $<0.05$ ). Hypertension (51.8%), type 2 diabetes (23.6%), coronary heart disease (20.9%), stroke (18.7%), and arrhythmia (11.2%) were the most prevalent five comorbidities. The proportion of hypertension was 27.0%, 45.4%, 53.0%, and 57.2% in each 5-year period with an increasing trend ( $P$  for trend  $<0.05$ ). The proportion of type 2 diabetes was 9.8%, 22.8%, 23.5%, and 26.0% in each 5-year period ( $P$  for trend  $<0.05$ ). Similar increasing trends were found in myocardial infarction, arrhythmia, and tumor. On the contrary, the proportion of patients with major postoperative complications decreased from 2000 to 2019, with 23.0%, 14.6%, 6.5%, and 5.6% in each 5-year period ( $P$  for trend  $<0.05$ ). For each specific postoperative complication, i.e. pneumonia, cardiovascular event, respiratory failure, and in-hospital death, similar decreasing trends were found (all  $P$  for trend  $<0.05$ ).

**Conclusion:** This descriptive analysis sheds light on the fact that the health status of the hip fracture population tends to shift gradually. Improving concepts and practices of clinical interventions may help reduce postoperative complications, whereas challenges in the management of comorbidities increase.

**Key words:** Comorbidity; Hip fracture; Postoperative complications; Trends

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## Introduction

With the aging population, geriatric hip fracture has become a major health problem across the globe due to high risk of morbidity, mortality, severe disability, and heavy social economic burden<sup>1–6</sup>. It has been estimated that over 1.6 million geriatric hip fractures occurred in 2000. Moreover, this number will increase to approximately 6.3 mn in 2050 around the world<sup>7</sup>. Currently, about a four-fold increase in the total absolute number of geriatric hip fracture patients was observed from 2012 to 2016 in China<sup>8</sup>. However, the prognosis of hip fracture is not satisfying even after appropriate surgical management. According to a report from the United Kingdom, about 10% of elderly patients who had hip fracture died within 1 month, and up to 30% died within 1 year<sup>9</sup>. Furthermore, among those who survived, about 58% had difficulty walking without assistive devices in the first year after hip fracture surgery and around one-third eventually ended up completely dependent<sup>10,11</sup>. A recent nationwide cohort study reported that the total hospitalization costs for hip fracture patients sharply increased from US\$60 mn to US\$380 mn from 2012 to 2016 in China<sup>8</sup>.

Comorbid conditions have a considerable impact on the prognosis of hip fracture patients and make perioperative management challenging. Previous compelling evidence showed that preoperative comorbidities are closely related to postoperative complications and mortality. A prospective observational cohort study reported that previous respiratory disease (OR, 2.7; 95% CI, 1.9–3.8), renal disease (OR, 2.3; 95% CI, 1.2–4.3), Parkinson's disease (OR, 1.9; 95% CI, 1.0–3.6), and stroke (OR, 1.5; 95% CI, 1.0–2.2) were all important risk factors for developing a postoperative chest infection<sup>12</sup>. Moreover, a history of cardiovascular disease (OR, 2.3; 95% CI, 1.6–3.4) was a significant risk for developing postoperative heart failure<sup>12</sup>. In addition, patients with a history of stroke were at an increased risk of a second stroke after hip fracture surgery (OR, 4.7; 95% CI, 2.3–9.8)<sup>12</sup>. Furthermore, the presence of three or more comorbidities (HR, 2.5; 95% CI, 1.6–3.9), respiratory disease (HR, 1.8; 95% CI, 1.3–2.5), and malignancy (HR, 1.5; 95% CI, 1.0–2.3) were all significantly associated with 30-day mortality after hip fracture surgery<sup>12</sup>. Another study also reported that common comorbidities such as ischemic heart disease (OR, 2.2; 95% CI, 1.0–4.9) and malignancy (OR, 2.5; 95% CI, 1.1–5.7) are associated with higher risk of 6-month mortality following hip fracture surgery in the elderly<sup>13</sup>. In addition, the Charlson Comorbidity Index (CCI), a useful indicator of comorbidity burden, has been shown to be associated with postoperative complications<sup>14</sup>. Patients with moderate to severe comorbidities were 1.45 times more likely to develop postoperative complications than those with mild ones (OR, 1.45; 95% CI, 1.05–1.99)<sup>14</sup>. The CCI was a strong predictor of both short-term and long-term mortality, including in-hospital mortality (OR, 1.40; 95% CI, 1.12–1.77), 30-day mortality (OR, 1.33; 95% CI, 1.09–1.63), 90-day mortality (OR, 1.36; 95% CI, 1.16–1.59), and 2-year mortality (OR,

1.36; 95% CI, 1.24–1.50)<sup>15</sup>. Thus, a better understanding of comorbid conditions of the geriatric hip fracture population would be conducive to making informed clinical decisions, reducing postoperative complications, and improving prognosis.

Over the last two decades, China has transformed into an aging society and has 12.6% of the population over 65 years old, according to the latest report from the National Bureau of Statistics of China in 2020<sup>16</sup>. It has been projected that the aged population would reach 27.9% by 2050<sup>16</sup>. The demographic aging leads to tremendous changes in the comorbid disease pattern of the population. According to the 2020 Report of Nutrition and Chronic Disease Status of Chinese Residents, the prevalence of chronic diseases in China is increasing rapidly. In 2019, among Chinese citizens over 18 years old, the prevalence of hypertension, type 2 diabetes, hypercholesterolemia was 27.5%, 11.9%, and 8.2%, respectively<sup>17</sup>. More alarmingly, major chronic diseases, namely cardiovascular diseases, cancer, chronic obstructive pulmonary disease (COPD), and type 2 diabetes, contributed 16.5% to premature mortality in 2019<sup>17</sup>. It is likely that the prevalence of these common conditions may also increase in hip fracture populations, according to the published data from the United States and European countries<sup>18–21</sup>. In the United States, increasing comorbidity trends were observed for sleep apnea (1.2% to 4.3%), weight loss (3.1% to 7.1%), and obesity (2.6% to 5.4%) in patients with geriatric hip fractures from 2006 to 2016<sup>18</sup>. According to a report from Denmark, the prevalence of malignancy and dementia decreased, while the prevalence of all other common comorbidities increased from 1999 to 2012, with the greatest increase in congestive heart failure (men: 6.5% to 10.7%, women: 5.9% to 13.1%), moderate to severe liver disease (men: 0.1% to 0.7%, women: 0.1% to 0.4%), and renal disease (men: 0.4% to 2.0%, women: 0.3% to 1.1%)<sup>20</sup>. However, few studies have examined the secular trends in comorbidities and postoperative complications of Chinese geriatric hip fracture patients.

Therefore, the purposes of this study were: (i) to quantify the secular trends in baseline comorbid conditions of geriatric hip fracture patients from 2000 to 2019 in the Chinese PLA General Hospital; (ii) to describe the major postoperative complications, mainly including pneumonia, cardiovascular disease, and in-hospital death; and (iii) to highlight the challenges in perioperative hip fracture management.

## Methods

### Data Source

We used data from the Chinese PLA General Hospital Hip Fracture Cohort (PLAGH Hip Fracture Cohort)<sup>22</sup>. The PLAGH Hip Fracture Cohort is a tertiary hospital-based cohort study evaluating the prognosis of hip fracture patients. This study included hip fracture patients (with a diagnosis of femoral neck fracture or intertrochanteric fracture) from 1 January 1991 to 19 December 2019.

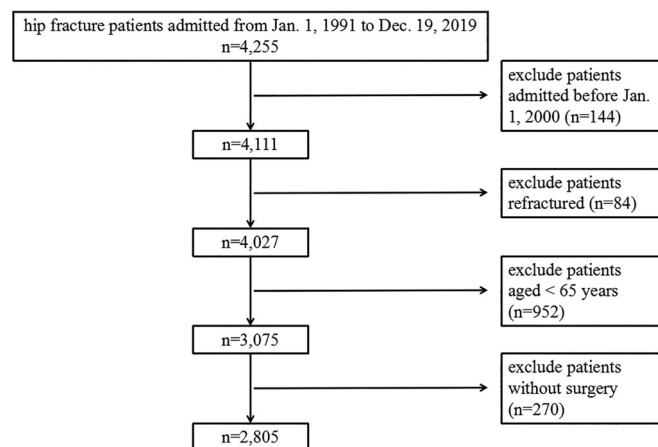
Demographic features, fracture information, comorbidities, surgical treatment, as well as lab test results of qualified patients were extracted from the electronic medical records. This study has been approved by the ethics committee of the Chinese PLA General Hospital.

### Study Population

Inclusion criteria included: (i) aged 65 years or older; (ii) received hip fracture surgery. Exclusion criteria included: (i) patients with a second hip fracture; (ii) patients who did not receive surgery treatment (Fig. 1). In this analysis, we included patients who were hospitalized for their first hip fracture with a diagnosis of femoral neck fracture or intertrochanteric fracture from 1 January 2000 to 19 December 2019. All the included patients had a clear hip diagnosis based on injury history, clinical manifestations, and imaging examinations, such as X-ray, computed tomography (CT) scan, or magnetic resonance imaging (MRI) examination. Patients were classified into four groups based on the admission year, namely, 2000–2004, 2005–2009, 2010–2014, and 2015–2019.

### Baseline Information

We extracted demographic information (age, gender, height, and weight) of the qualified patients. Information on the baseline comorbidities, including pneumonia (defined as occurring 3 months before surgery), COPD, type 2 diabetes, hypertension, heart failure, arrhythmia, coronary heart disease, myocardial infarction, chronic renal failure, stroke, stroke sequelae (defined as remaining language, mental, or physical dysfunction after stroke), dementia, tumor, and rheumatic diseases were also collected. In addition, the CCI, a well-established tool evaluating the chronic disease burden of patients, was also calculated. It assigns a numerical value



**Fig 1** Study population. We included 2805 patients who were aged 65 years or older and received hip fracture surgery between 1 January 2000 and 19 December 2019 using data from the Chinese PLA General Hospital Hip Fracture Cohort. Patients with a second hip fracture were excluded.

of 1, 2, 3, or 6 to 16 specific chronic diseases<sup>23</sup>. We classified our patients into three categories based on the following: CCI scores of 0, 1, >1.

### Major Complications

Since each postoperative complication was rare, we defined a composite endpoint of major complications, including pneumonia, respiratory failure, gastrointestinal bleeding, pulmonary embolism, angina pectoris, myocardial infarction, heart failure, arrhythmia, stroke, and in-hospital death. We summed up all these events adjudicated by medical specialists based on clinical symptoms, postoperative laboratory tests, or imaging examinations. Major complications are the composite indicator that can better indicate the secular trend.

### Major Cardiovascular Complications

We defined a composite endpoint of major cardiovascular complications, including pulmonary embolism, angina pectoris, myocardial infarction, heart failure, arrhythmia, stroke, and in-hospital death. We summarized all these events determined by medical experts based on clinical manifestation, laboratory, or imaging examinations. Major cardiovascular complications help to focus on the circulatory system and guide clinical decisions.

### Other Frequent Complications

We defined other frequent complications as the common specific postoperative ones. We extracted the number of events and calculated the frequency, respectively, and the in-hospital mortality in each 5-year period from 2000 to 2019 following accurate diagnosis by medical experts. Other frequent complications contribute to drawing attention to specific common ones and instructing targeted treatment.

### Health Resource Usage

We also described several health resource usages, including use of rescue therapy (defined as received rescue therapy in the intensive care unit after surgery), length of stay (from admission to discharge), and time to surgery (from admission to surgery). All the information was directly extracted from the electronic medical record. Health resource usage is conducive to promoting the rational allocation of clinical health resources.

### Perioperative Management Guidelines

We defined perioperative management guidelines as ones on hip fracture over the past 20 years from both domestic and overseas societies. We searched the CNKI, PubMed, and Embase databases using the following searching algorithms: “(hip fractures [MeSH Terms]) AND (practice guideline [MeSH Terms])”. Perioperative management guidelines are conducive to guiding the comprehensive treatment of geriatric hip fracture.

### Statistical Analysis

Variables of different types were described and analyzed by different methods accordingly. For categorical variables such as sex, comorbidities, and postoperative complications, numbers and frequencies were presented and analyzed by the chi-squared or Fisher's exact test. The ordinal variable, CCI, was also expressed numerically and with frequency, but was analyzed using the row mean scores difference test. Continuous variables such as age and body mass index (BMI) were expressed by mean and standard deviation, and analyzed by one-way analysis of variance. Trends in comorbidities and postoperative complications were examined by the Cochran-Armitage trend test. Days were represented by the median and interquartile range (IQR). We performed a series of exploratory subgroup analyses of major complications stratified by age (<75 and ≥75 years), gender (male and female), fracture type (intertrochanteric fracture and femoral neck fracture), and CCI (0, 1, and >1). All analyses were performed by RStudio (Version 1.4.1106, Public Benefit Corporation, Delaware, America). The observed significance level of a test or  $\alpha$  value is 0.05. All the tests were two-tailed, and  $P < 0.05$  was considered statistically significant.

## Results

### Baseline Information

Of all the 2,805 patients included, the overall average age was  $79.1 \pm 7.3$  years (mean  $\pm$  standard deviation, SD), 69.1% were women, and the mean BMI was  $22.7 \pm 3.8$ . The demographic characteristics were presented in each 5-year period (2000–2004, 2005–2009, 2010–2014, and 2015–2019) (Table 1). The mean age of the patients included in each 5-year period was  $78.3 \pm 7.3$  years,  $78.3 \pm 7.4$  years,  $79.2 \pm 7.0$  years, and  $79.6 \pm 7.4$  years, respectively. The proportion of females was 59.8%, 65.3%, 68.4%, and 73.0%, respectively, with a significant trend of increase ( $P$  for trend <0.001). The corresponding mean BMI was  $22.6 \pm 0.1$ ,  $22.3 \pm 3.1$ ,  $22.9 \pm 4.3$ , and  $22.7 \pm 4.0$ , without a significant trend difference.

Of all the preoperative comorbidities, hypertension (52.0%) was the most prevalent one, followed by type 2 diabetes (23.6%), coronary heart disease (20.9%), stroke (18.7%), and arrhythmia (11.2%). The prevalence of comorbidities varied over time. The proportion of hypertension was 27.0%, 45.4%, 53.0%, and 57.2% in each 5-year period from 2000 to 2019, with a sharp upward trend ( $P$  for trend <0.001). Similar obvious increasing trends were found in type 2 diabetes (9.8%, 22.8%, 23.5%, and 26.0%,  $P$  for trend <0.001) and tumor (3.3%, 5.1%, 7.4%, and 11.7%,  $P$  for trend <0.001). Trends were also observed as elevated over time in myocardial infarction, arrhythmia, and sequela of stroke (all  $P$  for trend <0.001) (Table 1).

The overall percentages of patients with a CCI score of 0, 1, and >1 were 43.9%, 30.1%, and 26.1%, respectively. The proportion of patients with a CCI score of >1 had a sharp increase trend from 2000 to 2019 (19.7%, 20.4%, 23.7%, and

32.6%,  $P$  for trend <0.001). On the contrary, the proportion of patients with a CCI score of 0 significantly decreased (57.4%, 46.8%, 46.4%, and 37.8%, respectively) (Table 1).

### Major Complications

Of the 2,805 patients, the overall proportion of major complications was 8.6%. The proportion of major complications decreased significantly from 2000 to 2019 (23.0%, 14.6%, 6.5%, and 5.6% in each 5-year period,  $P$  for trend <0.001) (Table 1). Subgroup analyses stratified by age, gender, fracture type, and CCI of major complications showed similar declining trends (Table 2, Fig. 2).

### Major Cardiovascular Complications

The overall proportion of postoperative major cardiovascular complications was 6.8%. A sharp decreasing trend was also observed for major cardiovascular complications from 2000 to 2019 (15.6%, 11.7%, 5.2%, and 4.5%,  $P$  for trend <0.001) (Table 1).

### Other Frequent Complications

Other frequent postoperative complications in hip fracture patients included fever (4.4%), pneumonia (3.5%), stroke (1.7%), respiratory failure (1.1%), and myocardial infarction (0.4%) from 2000 to 2019. Decreasing trends over time were also observed in fever, pneumonia, stroke, respiratory failure, and myocardial infarction (all  $P$  for trend <0.05). The proportion of in-hospital mortality in each 5-year period was about 2.5%, 2.4%, 1.0%, and 0.6%, respectively, showing a significant downward trend (Table 1).

### Health Service Usage

Over the past 20 years, rescue therapy was common after surgery, and 10.4% of the patients received rescue therapy in the intensive care unit. The overall median length of stay was 12.0 days (interquartile range, IQR, 6.0 days), and the overall median time to surgery was 5.0 days (IQR, 4.0 days) from 2000 to 2019. The median length of stay decreased from 18.0 days (IQR, 5.5 days) in 2000 to 9.0 days (IQR, 5.0 days) in 2019, while the median time to surgery remained stable at around 5.0 days (Fig. 3).

### Perioperative Management Guidelines

We found six guidelines published from 2000 to 2019. One of the most influential guidelines was the Management of Hip Fractures in the Elderly: Evidence-based Clinical Practice Guideline initiated by the American Academy of Orthopaedic Surgeons (AAOS) in 2014<sup>24</sup>. Other important guidelines included the Management of Hip Fracture in Older People, A National Clinical Guideline proposed by the Society of Scottish Intercollegiate Guidelines Network (SIGN) (released in 1997, updated in 2002 and 2009)<sup>25</sup>, the Improving Time to Surgery, Management of Hip Fracture Patients launched by the Bone and Joint Health Network in Canada in 2010<sup>26</sup>, the Management of Hip Fracture in Adults published by the National Institute for Health and



TABLE 1. Characteristics of hip fracture patients aged 65 years and above from 2000 to 2019

	2000– 2004 (N = 122)	2005– 2009 (N = 588)	2010–2014 (N = 1087)	2015–2019 (N = 1008)	Statistic value	P value	P for trend
Age (mean (SD))	78.34 (7.31)	78.26 (7.40)	79.17 (6.98)	79.59 (7.42)	F = 8.63	0.003**	—
Female (%)	73 (59.8)	384 (65.3)	744 (68.4)	736 (73.0)	$\chi^2 = 16.31$	0.001**	<0.001***
BMI (mean (SD))	22.59 (0.08)	22.32 (3.12)	22.92 (4.25)	22.74 (3.95)	F = 3.19	0.024*	—
Comorbidities							
Pneumonia (%)	1 (0.8)	17 (2.9)	25 (2.3)	39 (3.9)	$\chi^2 = 6.57$	0.087	0.053
COPD (%)	0 (0.0)	41 (7.0)	65 (6.0)	52 (5.2)	—	0.004**	0.837
Type 2 diabetes (%)	12 (9.8)	134 (22.8)	255 (23.5)	262 (26.0)	$\chi^2 = 16.23$	0.001**	0.001**
Hypertension (%)	33 (27.0)	267 (45.4)	576 (53.0)	577 (57.2)	$\chi^2 = 52.13$	<0.001***	<0.001***
Heart failure (%)	4 (3.3)	8 (1.4)	12 (1.1)	9 (0.9)	$\chi^2 = 5.56$	0.135	0.065
Arrhythmia (%)	0 (0.0)	18 (3.1)	181 (16.7)	114 (11.3)	—	<0.001***	<0.001***
Coronary heart disease (%)	31 (25.4)	129 (21.9)	201 (18.5)	225 (22.3)	$\chi^2 = 6.93$	0.074	0.881
Myocardial infarction (%)	0 (0.0)	29 (4.9)	49 (4.5)	80 (7.9)	—	<0.001***	<0.001***
Chronic kidney disease (%)	7 (5.7)	19 (3.2)	29 (2.7)	37 (3.7)	$\chi^2 = 4.10$	0.251	0.827
Stroke (%)	26 (21.3)	107 (18.2)	194 (17.8)	198 (19.6)	$\chi^2 = 1.75$	0.625	0.733
Stroke sequela (%)	1 (0.8)	19 (3.2)	53 (4.9)	81 (8.0)	$\chi^2 = 24.29$	<0.001***	<0.001***
Dementia (%)	11 (9.0)	44 (7.5)	34 (3.1)	39 (3.9)	$\chi^2 = 23.32$	<0.001***	<0.001***
Tumor (%)	4 (3.3)	30 (5.1)	80 (7.4)	118 (11.7)	$\chi^2 = 28.66$	<0.001***	<0.001***
Malignant tumor (%)	2 (1.6)	24 (4.1)	55 (5.1)	74 (7.3)	$\chi^2 = 12.70$	0.005**	<0.001***
Rheumatic disease (%)	2 (1.6)	23 (3.9)	18 (1.7)	7 (0.7)	$\chi^2 = 22.15$	<0.001***	<0.001***
CCI (%)					$\chi^2_{OMH} = 41.62$	<0.001***	—
0	70 (57.4)	275 (46.8)	504 (46.4)	381 (37.8)			<0.001***
1	28 (23.0)	193 (32.8)	325 (29.9)	298 (29.6)		0.85	0.85
>1	24 (19.7)	120 (20.4)	258 (23.7)	329 (32.6)			<0.001***
Postoperative in-hospital complications							
Major complications <sup>†</sup> (%)	28 (23.0)	86 (14.6)	71 (6.5)	56 (5.6)	$\chi^2 = 76.19$	<0.001***	<0.001***
Major cardiovascular complications <sup>‡</sup> (%)	19 (15.6)	69 (11.7)	57 (5.2)	45 (4.5)	$\chi^2 = 50.42$	<0.001***	<0.001***
Fever (%)	48 (39.3)	38 (6.5)	12 (1.1)	26 (2.6)	$\chi^2 = 394.36$	<0.001***	<0.001***
Pneumonia (%)	14 (11.5)	38 (6.5)	28 (2.6)	18 (1.8)	$\chi^2 = 49.86$	<0.001***	<0.001***
Respiratory failure (%)	0 (0.0)	13 (2.2)	13 (1.2)	5 (0.5)	—	0.013*	0.037*
Myocardial infarction (%)	3 (2.5)	3 (0.5)	1 (0.1)	4 (0.4)	—	0.007**	0.046*
Stroke (%)	7 (5.7)	20 (3.4)	11 (1.0)	11 (1.1)	$\chi^2 = 26.64$	<0.001***	<0.001***
Rescue (%)	8 (6.6)	65 (11.1)	104 (9.6)	115 (11.4)	$\chi^2 = 4.11$	0.248	0.259
Death (%)	3 (2.5)	14 (2.4)	11 (1.0)	6 (0.6)	$\chi^2 = 11.86$	0.008**	0.001**

BMI, body mass index; CCI, Charlson comorbidity index; COPD, chronic obstructive pulmonary disease;  $\chi^2_{OMH}$ , Cochran–Mantel–Haenszel chi-square test; <sup>†</sup> Major complications, including postoperative in-hospital pneumonia, respiratory failure, gastrointestinal bleeding, and major cardiovascular complications; <sup>‡</sup> major cardiovascular complications; \* P < 0.05; \*\* P < 0.01; \*\*\* P < 0.001.

Care Excellence (NICE) of the United Kingdom (released in 2011, updated in 2017)<sup>9</sup>, the Guideline for Hip Fracture released by the Australian and New Zealand Hip Fracture Registry (ANZHFR) in 2014<sup>27</sup>, and the Guidelines

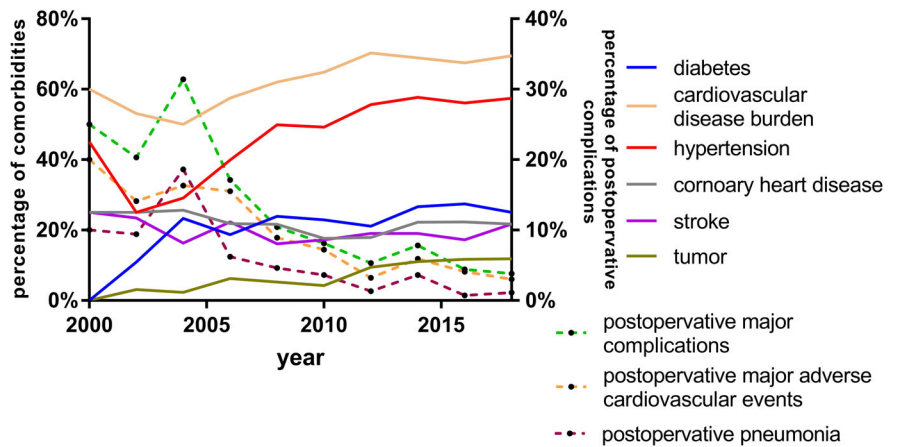
for Diagnosis and Treatment of Adult Femoral Neck Fractures developed by the Traumatic Orthopaedics Group, Society of Orthopedics, Chinese Medical Association in 2018<sup>28</sup> (Fig. 3).

**TABLE 2 Subgroup analysis of major complications in geriatric hip fracture patients from 2000 to 2019**

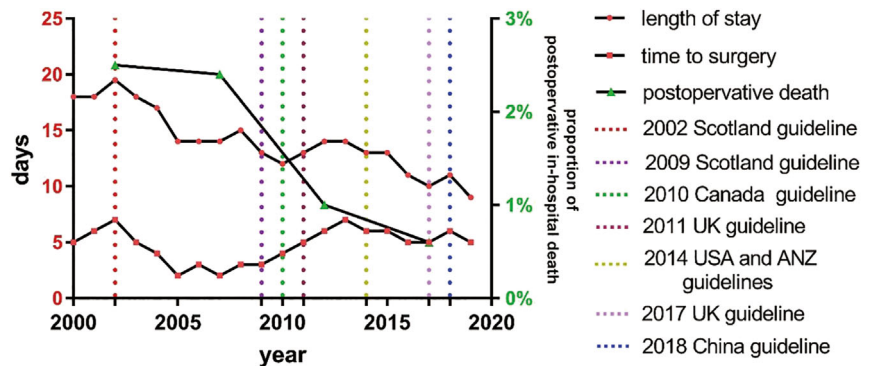
	2000–2004	2005–2009	2010–2014	2015–2019	P for trend
Age (%)					
<75 years	9 (20.5)	15 (7.2)	14 (4.4)	15 (5.4)	0.006**
≥75 years	19 (24.4)	71 (18.6)	57 (7.4)	41 (5.6)	<0.001***
Gender (%)					
Male	8 (16.3)	33 (16.2)	21 (6.1)	19 (7.0)	<0.001***
Female	20 (27.4)	53 (13.8)	50 (6.7)	37 (5.0)	<0.001***
Fracture type (%)					
Intertrochanteric fracture	28 (23.0)	58 (19.7)	27 (5.2)	24 (5.6)	<0.001***
Femoral neck fracture	0 (0)	28 (9.5)	44 (7.8)	32 (5.5)	0.024*
CCI (%)					
0	15 (21.4)	27 (9.8)	21 (4.2)	13 (3.4)	<0.001***
1	6 (21.4)	36 (18.7)	20 (6.2)	17 (5.7)	<0.001***
>1	7 (29.2)	23 (19.2)	30 (11.6)	26 (7.9)	<0.001***

Major complications, including postoperative in-hospital pneumonia, respiratory failure, gastrointestinal bleeding, pulmonary embolism, angina pectoris, myocardial infarction, heart failure, arrhythmia, stroke, and death. CCI, Charlson comorbidity index.; \*P < 0.05.; \*\*P < 0.01.; \*\*\*P < 0.001.

**Fig 2** Trends in comorbidities and postoperative complications from 2000 to 2019. Trends in comorbidities increased from 2000 to 2019, including type 2 diabetes, cardiovascular disease burden, hypertension, coronary heart disease, stroke, and tumor. And trends in postoperative major complications, major cardiovascular complications and pneumonia declined over time.



**Fig 3** Trends in length of stay, time to surgery, and in-hospital mortality from 2000 to 2019. The annual median length of stay decreased from 18.0 days (IQR, 5.5 days) in 2000 to 9.0 days (IQR, 5.0 days) in 2019. The annual median time to surgery remained stable at around 5.0 days. The average in-hospital mortality every 5 years declined (2.5%, 2.4%, 1.0%, and 0.6%). ANZ, Australia and New Zealand; UK, the United Kingdom; USA, the United States of America.



## Discussion

### Main Findings

This descriptive analysis highlights the secular trends in comorbidities and postoperative complications of geriatric hip fracture patients from 2000 to 2019. We found that the proportion of major preoperative comorbidities, like hypertension, type 2 diabetes, coronary heart disease, stroke, arrhythmia, myocardial infarction, and tumor increased significantly. In contrast, the proportion of postoperative major complications, major cardiovascular complications, pneumonia, stroke, and in-hospital mortality declined over time.

### Comparison with Previous Studies

Hip fracture typically occurs in the geriatric population. A recent study examined femoral neck fracture patients from 2010 to 2019 in China and found an aging trend of the study subjects, with an average age of  $72.2 \pm 15.6$  years (mean  $\pm$  SD)<sup>29</sup>. In our study, we included both femoral neck fracture patients and intertrochanteric fracture patients; the average age was slightly higher ( $79.1 \pm 7.3$ ) years. Patients with greater age often have a high comorbidity burden, which makes perioperative management challenging. The above-mentioned study showed that 79.1% of hip fracture patients had pre-existing comorbidities, and the types of comorbidities were significantly higher during 2015–2019 than during 2010–2014<sup>29</sup>. In addition, most of the patients were women, suggesting the importance of osteoporosis prophylaxis or treatment in this high-risk population.

Previous studies from United States and European countries have shown a high comorbidity burden among hip fracture patients. A study based on a claims database in a representative US population found that pre-existing comorbidities increased in hip fracture patients from 2006 to 2016<sup>18</sup>. These comorbidities included hypertension, type 2 diabetes, renal failure, rheumatoid arthritis, hypothyroidism, coagulation deficiency, peripheral vascular disorder, and depression<sup>18</sup>. The proportion of patients with three or more comorbidities increased from 33.9% in 2006 to 43.4% in 2016<sup>18</sup>. In Canada, similar increasing trends were observed for hypertension (5.8% to 6.1%), type 2 diabetes (1.9% to 4.1%), and arrhythmia (7.9% to 11.3%) from 2004 to 2012<sup>21</sup>. In the current study, we showed that major pre-existing comorbidities, including hypertension, type 2 diabetes, coronary heart disease, stroke, arrhythmia, myocardial infarction, and tumor, were increasing rapidly from 2000 to 2019.

Over the past 20 years, many new treatment concepts and surgical techniques had been introduced to the management of hip fracture and greatly improved the prognosis of these patients. Previous studies have shown a decline in postoperative complications and mortality in hip fracture patients. A national hip fracture cohort study from the United States found that the overall complication rate significantly decreased from 51.1% in 2009 to 38.4% in 2016, and mortality decreased from 2.9% in 2009 to 2.4% in 2016<sup>19</sup>. Myocardial infarction, deep vein thrombosis, pulmonary

embolism, pneumonia, and urinary tract infection were the major postoperative complications that had decreased considerably. These results are consistent with the current study. In our study, we found similar decreasing trends in postoperative major complications, major cardiovascular complications, and some frequent complications such as pneumonia, stroke, respiratory failure, myocardial infarction, and in-hospital mortality. The reduced post-surgery complications could be achieved through a coordinated multidisciplinary team, including orthopaedists, anesthesiologists, internists, and intensivists.

The benefit of surgical intervention has been well-documented, and surgery is indicated for most patients with hip fractures<sup>30</sup>. Current guidelines from major societies suggest early surgical intervention within 24 hours for stable patients without baseline conditions. For those with comorbid medical illness, surgery is recommended as soon as feasible. A meta-analysis reported that the risk of death among patients who received earlier surgery (within 72 h) compared with that of delayed surgery was significantly lower (RR, 0.81; 95% CI, 0.68–0.96)<sup>31</sup>. Undoubtedly, early surgical intervention has an important impact on the prognosis<sup>32</sup>, but there is no consensus on the optimal timing that fits all patients, especially for patients with multiple comorbidities. Individuals with multiple comorbidities often require extensive preoperative evaluation and stabilization of these conditions before hip fracture surgery. Failure to optimize pre-existing conditions may increase the risk of postoperative complications. Extensive preoperative evaluation and accompanying management often lead to prolonged time to surgery. In our data, the time to surgery between 2003 and 2007 was about 2.0–3.0 days, but in-hospital death during that time was high. In the following years, when adequate preoperative evaluation and comprehensive management were prioritized, the in-hospital mortality decreased gradually. These data suggest that time to surgery is a very important index, but reducing time to surgery is not our ultimate goal. Since there is a trade-off between early surgery and extensive preoperative management, surgeons should make decisions on a case-by-case basis and find the optimal pathway for each patient. A multidisciplinary team in this situation may be very helpful and is highly recommended.

### Recommendations on Management of the Hip Fracture

Over the last two decades, high-quality evidence led to the implementation of many good clinical practices on hip fracture management, including antithrombotic prophylaxis, pain and emotion management, and enhanced recovery after surgery (ERAS). Antithrombotic prophylaxis can significantly reduce the incidence of symptomatic deep vein thrombosis and pulmonary embolism<sup>33</sup>. Nowadays, routine ultrasound tests, dynamic monitoring of D-dimer level, thrombosis risk evaluation, use of anticoagulants and non-pharmaceutical treatments, and early mobilization are recommended for hip fracture patients. Due to trauma and concerns about surgical risks, a large proportion of patients

may experience negative emotions such as anxiety, depression, and sleep disturbance. Adequate patient education, pre-operative communication, postoperative rehabilitation guidance, and use of sedation and anti-anxiety medications can improve the mental and psychological state of these patients. Pain can cause physical or psychological stress. Studies have shown that pain is associated with an increased risk of postoperative complications such as delirium, leading to a prolonged hospital stay, delayed physical rehabilitation, and impaired function<sup>34</sup>. According to the major guidelines, non-steroidal anti-inflammatory drugs can be routinely used for patients without strong contraindications<sup>35</sup>. ERAS represents a paradigm shift in perioperative management. It replaces traditional experience with evidence-based practices and covers all aspects of the patient's operation. Postoperative complications and hospital length of stay were significantly lower among patients undergoing the ERAS approach<sup>36</sup>. All these good practices can benefit the patients and contribute to a safe and quick recovery after surgery.

In conclusion, the comorbid disease pattern of the hip fracture population is changing rapidly, and we are facing more challenges for the management of hip fractures. In the near future, more efforts should be emphasized on multi-disciplinary hip fracture care service, perioperative evaluation, comorbidity stabilization, individualized functional rehabilitation, fracture liaison service, and pharmacological treatment for prevention of secondary fractures.

### Strengths and Limitations

The major strength of this study is we used data from a large hip fracture cohort with a wide range of time periods from 2000 to 2019. These data enabled us to examine the secular trend of comorbidities and complications over two decades. However, this study has several limitations. First, we presented single-center data, which might not be representative of patients nationally. However, comorbidity and complication patterns for this population are consistent with previous reports from United States and European countries, indicating a reasonable validity and representativeness of this single-center population. Second, we did not examine the causes of the decreasing postoperative complications in this analysis; future studies are needed to extensively examine the effectiveness of interventions that may reduce postoperative complications. Last, we did not examine the associations between multiple comorbidities and long-term prognosis. Ideally, this question could be examined in studies with a multi-center prospective cohort design.

### Conclusion

This descriptive analysis sheds light on the fact that the health status of the hip fracture population tends to shift gradually. Improving concepts and practices of clinical interventions may help reduce postoperative complications, whereas challenges in the management of comorbidities increase.

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