Archives of Osteoporosis (2020) 15: 183
https://doi.org/10.1007/s11657-020-00847-9

ORIGINAL ARTICLE

Osteoporotic hip fracture mortality and associated factors in Hawai'i

Kaitlin Hori[1] · Andrea M. Siu[2] · Edward T. Nguyen[3] · Samantha N. Andrews[4,5] · So Yung Choi[6] · Hyeong Jun Ahn[6] · Cass K. Nakasone[4] · Sian Yik Lim[3,4]

Received: 22 April 2020 / Accepted: 26 October 2020 / Published online: 16 November 2020

Abstract

Summary The 30-day mortality of osteoporotic hip fracture patients ≥ 50 years at Hawai'i Pacific Health (2015–2016) was 4.2%. Mortality increased to 17.1% (1 year), 24.5% (2 years), and 30.1% (3 years). Increased age, male sex, higher CCI score, primary insurance status-Medicare/Medicaid, and lower BMI were associated with increased mortality.

Purpose The objective of this study was to evaluate mortality and factors associated with mortality of osteoporotic hip fracture patients at community hospitals within a large healthcare system in Hawai'i.

Methods A retrospective chart review was conducted of 428 patients, ≥ 50 years, and hospitalized for a osteoporotic hip fracture from January 2015 to May 2016 within a large healthcare system in Hawai'i. Patient demographics, comorbidities, and treatment were collected from retrospective chart review. We determined the date of death by review of medical records and online public obituary records. We calculated 30-day, 90-day, 1-year, 2-year, and 3-year mortality after discharge for hip fracture admission. Multivariable logistic regression and proportional hazards regression were used to evaluate associations between variables and the mortality of the patients.

Results The 30-day and 90-day mortality after admission for hip fracture were 4.2% and 8.6%. One-year mortality, 2-year mortality, and 3-year mortality were 17.1%, 24.5%, and 30.1%, respectively. Through proportional hazards regression, older age (hazard ratio (HR) = 1.06, $p < 0.001$), high comorbidity load (HR = 1.30, $p < 0.001$), and primary insurance status-Medicare/Medicaid (HR = 3.78, $p = 0.021$) were associated with increased mortality, while female sex (HR = 0.54, $p < 0.001$) and higher BMI (HR = 0.94, $p = 0.002$) were associated with lower mortality.

Conclusion After admission for osteoporotic hip fracture, the 30-day mortality was 4.2%. At 1 year, 2 years, and 3 years, mortality increased to 17.1%, 24.5%, and 30.1%, respectively. Increased age, male sex, higher Charlson comorbidity index score, primary insurance status-Medicare/Medicaid, and lower body mass index were associated with increased mortality.

Keywords Hip fracture · Hospitalization · Osteoporosis · Mortality

Introduction

Osteoporotic hip fractures are a public health concern associated with significant morbidity, mortality, and healthcare cost [1, 2]. In the USA, over 300,000 individuals aged 65 and older are hospitalized for hip fractures [3]. Hip fractures in older individuals occur mainly due to falls and osteoporosis. Estimates of mortality rates 1 year after hip fracture range from 14 to 58% [4]. Recent studies have suggested a decrease in 1-year mortality rates for hip fractures as compared to studies from earlier years with an estimation of 1-year mortality rate after hip fracture of approximately 22% [5]. In the USA, adjusted 360-day mortality decreased from 24.0% in 1986 to 21.9% in 2004 in women, while decreasing from 40.6 to 32.5% in men [6].

✉ Sian Yik Lim
limsianyik@gmail.com

1 University of Southern California, Los Angeles, USA

2 Hawai'i Pacific Health Research Institute, Honolulu, HI, USA

3 Bone and Joint Center, Pali Momi Medical Center, Hawai'i Pacific Health, 98-1079 Moanalua Road, Suite 300, Aiea, HI 96701, USA

4 Straub Clinic, Hawai'i Pacific Health, Honolulu, HI, USA

5 Department of Surgery, University of Hawai'i, Honolulu, HI, USA

6 Department of Quantitative Health Sciences, University of Hawai'i, Honolulu, HI, USA

Mortality rates after osteoporotic hip fracture in Hawai'i are unknown and may differ from the contiguous USA due to unique characteristics in racial composition and the healthcare system in Hawai'i. Compared to the contiguous USA, Hawai'i has a distinct racial composition, where non-Hispanic whites do not form the majority of the population [7]. In Hawai'i, there is a higher proportion of Asians, Pacific Islanders, and multiracial persons [1, 8]. According to 2018 census data, 25.6% of the individuals living in Hawai'i identified themselves as being white, while 37.6%, 10.2%, and 10.7% identified themselves as Asian, Native Hawai'ian/Pacific Islander, or Hispanic/Latino [9]. Previous studies have shown that ethnicity affects mortality rates after hip fracture [9]. System factors may also impact mortality [10]. Low rates of uninsured individuals and good access to healthcare characterize the healthcare system of Hawai'i, and may affect fracture outcomes [11, 12].

Understanding the mortality of osteoporotic hip fractures within the community is critical in understanding the disease burden of hip fractures and osteoporosis and is the vital first step in improving outcomes and population health planning [6]. Currently, there is a lack of data about mortality after hip fracture in Hawai'i. Therefore, we conducted this study to evaluate mortality of patients who were admitted for hip fractures at three major hospitals within Hawai'i Pacific Health, a large healthcare system in Hawai'i.

Methods

Research setting and design

We conducted a retrospective chart review of patients admitted for hip fractures to three medical centers within the Hawai'i Pacific Health (HPH) system, one of the largest healthcare providers in the state. Hawai'i Pacific Health is a not-for-profit healthcare network of hospitals, clinics, physicians, and other care providers that cover the state of Hawai'i [13]. The study was reviewed and determined to be exempt from Institutional Review Board approval by the HPH Research Institute. HPH uses the Western Institutional Review Board (WIRB) as its local IRB. However, IRB exemption determinations are made by our Institutional Official and/or designee in accordance with HPH policies, HPH's contract with WIRB, and the Common Rule. A waiver of approval by an IRB was made by our Institutional Office and/or designee in accordance with the Office of Human Research Protections.

Study participants and analysis variables

Patients aged 50 years or older who had a hip fracture hospitalization from January 1, 2015, to May 31, 2016, were identified. We excluded patients with less than 1 year of follow-up data. We identified hip fracture cases using a primary discharge diagnosis ICD-10 codes of M80.05*, M80.85*, M84.35, M84.45, M84.55, M84.65, S32.4*, and S72*. There were 476 cases of hip fracture. Repeat admissions of the same patient ($n = 37$) within the study period were excluded because frequently they represented admissions for complications from hip fracture such as infection or other unrelated issues. Ten cases of hip fracture in neoplastic disease were excluded. There was one case of open transcervical fracture related to trauma and that was excluded. The remaining cases were confirmed to be non-traumatic hip fracture cases based on manual chart review. Non-traumatic fractures were defined as those resulting from a fall from standing height or less. No cases of Paget disease were identified.

Data extracted from the electronic medical record system included the age, gender, height, weight, body mass index (BMI), race, treatment facility, alcohol usage, charges associated with admission, and insurance type of the patient at the time of admission. Race/ethnicity data was from medical records, usually provided by patient self-report of their primary race identification. We had previously performed manual chart review to determine osteoporosis treatment 1 year after hip fracture admission [1]. Additional information was obtained in regard to the type of hip fracture the patient sustained and surgical repair (if any). We determined the comorbidities for the Charlson comorbidity index (CCI) from chart review. The CCI is one of the most widely used indexes of comorbidity [14]. CCI categorizes an individual's burden of disease, with each comorbidity category having an associated weight based on the adjusted risk of mortality or resource use [14, 15]. The sum of all weights results in a comorbidity score for patients. Zero indicates no comorbidities, while higher scores indicate greater comorbidity.

We determined dates of death from medical chart review of clinic charts and hospital medical records. We supplemented medical chart review by searching internet death records of patients using http://www.obitsarchive.com/. Online obituary websites are reliable and valid sources of survival data [16–18]. Traditionally, local newspapers published death notices. In recent years, death notices are being increasingly published in online newspaper obituaries. Orbitsarchive.com offers access to obituary notices published in newspapers in the USA. It also provides coverage of all the main newspapers in Hawai'i, including major newspapers on the Islands of Oahu and Kauai, where most of the patients were admitted.

We calculated descriptive statistics to summarize and understand the patients' healthcare record. For continuous variables, mean and standard deviations were calculated, and for categorical variables, frequency and percentages were calculated. Cost data were further summarized using median and interquartile range. We compared patients alive and deceased at 3 years, using two sample t tests for continuous variables and Fisher's exact tests for categorical variables. Kaplan-Meier curves were generated to estimate the survival functions

of the overall sample and by each racial group. Multivariable logistic regression of mortality was performed to identify factors associated with mortality at 30 days, 90 days, 1 year, 2 years, and 3 years with the odds ratios and 95% confidence intervals. Cox proportional hazards regression was then conducted on the associated variables to determine predictive factors for mortality after a hip fracture and hazard ratios with 95% confidence intervals were calculated. The starting time of analysis was January 1, 2015. We censored patients with whom the date of death was not available on July 25, 2019. We conducted analyses using R version 3.6.0 (R Foundation for Statistical Computing, Vienna, Austria). A p value of less than 0.05 was considered statistically significant. Control groups for multivariable logistic regression and proportional hazards regression were as follows: sex (male), treatment facility (Medical Center A), primary insurance status (private insurance). Because there were few patients (< 1% of patients) who reported two races/ethnicity groups as their primary race, the race/ethnicity groups are not mutually exclusive. The race variable does not have a specific reference group. The patients were allowed to choose multiple races and each racial group acts as a dummy variable. Each of the four racial groups works as a separate variable, instead of one aggregated race variable. For example, if a patient was categorized to both Native Hawaiian/Pacific Islander and Asian-American, this patient would be considered as controls for Caucasian and other, and as cases for Native Hawaiian/Pacific Islander and Asian-American. Possible predictor variables of mortality for the dataset were selected based on previous literature. Within our model, we included predictor variables using available variables in the dataset. The only variable that was not included in the model was alcohol usage, which we decided not to include because the data collected for alcohol usage was incomplete due to inconsistent recording within medical records. We assessed cost data for hip fracture admissions. The cost data consisted of the primary direct fixed cost and the primary direct variable cost. Primary direct fixed cost consisted of the cost of salaried labor, buildings, and equipment. Primary direct variable cost consisted of the cost of medication and supplies [19].

Table 1 Baseline characteristics of 428 patients with hip fracture

Variable	Mean ± SD or n (%)
Age, years	79.70 ± 11.26
Female	291 (68.0%)
Race*	
Native Hawaiian and Other Pacific Islander	22 (5.1%)
Asian-American	236 (55.1%)
Caucasian	164 (38.3%)
Other (African-American, Hispanic, other)	10 (2.3%)
Body mass index	23.29 ± 4.90
Treatment facility	
Medical Center A	171 (40.0%)
Medical Center B	139 (32.5%)
Medical Center C	118 (27.6%)
Alcohol usage	
Current	106 (24.8%)
None/past	313 (73.1%)
Unknown	9 (2.1%)
Primary insurance	
Medicare/Medicaid	373 (87.2%)
Private Health Insurance	54 (12.6%)
No insurance	1 (0.2%)
Charlson comorbidity index	1.50 ± 2.00
Length of stay, days	6.72 ± 6.39
Femoral neck fractures	197 (46.0%)
Intertrochanteric fractures	158 (36.9%)
No surgery	37 (8.6%)
Mortality	
30 days	18 (4.2%)
90 days	37 (8.6%)
1 year	73 (17.1%)
2 year	105 (24.5%)
3 year	129 (30.1%)

* Each race group is its own dummy variable and not mutually exclusive

Results

Characteristics of the study population

Over the study period, there were 428 hospitalizations with a primary diagnosis of an osteoporotic hip fracture. We summarize the characteristics of these patients admitted for a hip fracture in Table 1. The mean patient age was 79.7 years and 68% of these hospitalizations were females. The proportion of Caucasian and non-Caucasian was approximately 38% and 62%, respectively; Asian-Americans made up more than 50% of the study population. There were 4 patients who reported 2 separate races/ethnicity groups as their primary race. More than 80% of the osteoporotic hip fracture hospitalizations consisted of patients with Medicare or Medicaid as the primary payer. The mean CCI score was 1.5 (range 0–12). Prior to admission, 22.9% of patients received treatment for osteoporosis. In Table 2, we provide a comparison of alive and deceased patients at 3 years.

Treatment of hip fracture

Forty-six percent ($n = 197$) of patients had a femoral neck fracture, while 37% ($n = 158$) of patients had an intertrochanteric fracture. Approximately, 91% ($n = 391$) of patients had surgical repair of hip fracture, while 9% of

Table 2 Comparison of alive and deceased patients at 3 years

Variable	Mean ± SD or *n* (%)		*p*
	Alive at 3 years (*n* = 299)	Dead at 3 years (*n* = 129)	
Age, years	77.78 ± 11.28	84.16 ± 9.92	< 0.001
Female	214 (71.57%)	77 (59.69%)	0.0178
Race*			
Native Hawaiian and Other Pacific Islander	15 (5.02%)	7 (5.43%)	0.8159
Asian-American	152 (50.84%)	84 (65.12%)	0.008
Caucasian	125 (41.81%)	39 (30.23%)	0.030
Other (African-American, Hispanic, other)	9 (3.01%)	1 (0.78%)	0.2941
Body mass index	23.93 ± 4.82	21.79 ± 4.76	< 0.001
Treatment facility			0.1017
Medical Center A	120 (40.13%)	51 (39.53%)	
Medical Center B	89 (29.77%)	50 (38.76%)	
Medical Center C	90 (30.10%)	28 (21.71%)	
Primary insurance			< 0.001
Medicare/Medicaid	247 (82.61%)	126 (97.67%)	
Private Health Insurance	51 (17.06%)	3 (2.33%)	
No insurance	1 (0.33%)	0 (0.00%)	
Charlson comorbidity index	1.10 ± 1.54	2.41 ± 2.57	< 0.001
Length of stay, days	6.28 ± 6.50	7.74 ± 6.02	0.0262
Femoral neck fractures	142 (47.49%)	55 (42.64%)	0.3981
Intertrochanteric fractures	109 (36.45%)	49 (37.98%)	0.8273
No surgery	21 (7.02%)	16 (12.40%)	0.0903

Two sample *t* tests for the continuous variables, and Fisher's exact tests for the categorical variables

patients did not have surgery for their hip fracture. Among the patients who had surgery, 120 patients had hemiarthroplasty, 28 patients had total hip arthroplasty, while other patients received reduction and fixation surgery. Only 115 (26.9%) patients received osteoporosis medication for secondary prevention 1 year after hip fracture, with the most common medication being oral bisphosphonates [1].

Mortality after hip fracture hospitalization

The mortality for the patients admitted for osteoporotic hip fracture at 30 days, 90 days, 1 year, 2 years, and 3 years is summarized in Table 1. The cumulative number of deaths at 30 days and 90 days after discharge was 18 and 37, with the corresponding 30-day and 90-day mortality rates at 4.2% and 8.6%. The cumulative number of deaths continued to increase in years 1, 2, and 3 after discharge, with the cumulative number of deaths reported as 73, 105, and 129. Mortality at 1, 2, and 3 years was 17.1%, 24.5%, and 30.1%. Figure 1 shows the Kaplan-Meier curve for all hip fracture patients in the study. Figure 2 shows the Kaplan-Meier curve by each racial group. The differences of mortality between racial groups were not statistically significant.

Factors predicting mortality after hip fracture hospitalization

Short-term mortality (30-day and 90-day mortality)

At 30 days, multivariable logistic regression (Table 3) showed that older age and male sex were associated with increased mortality. Regarding 90-day mortality, multivariable logistic

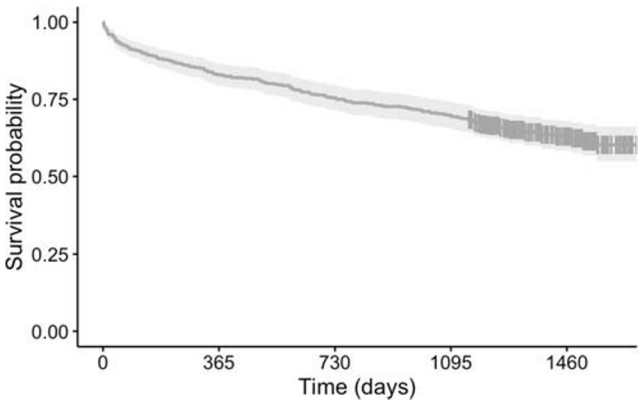

Fig. 1 Kaplan-Meier curve all hip fracture patients

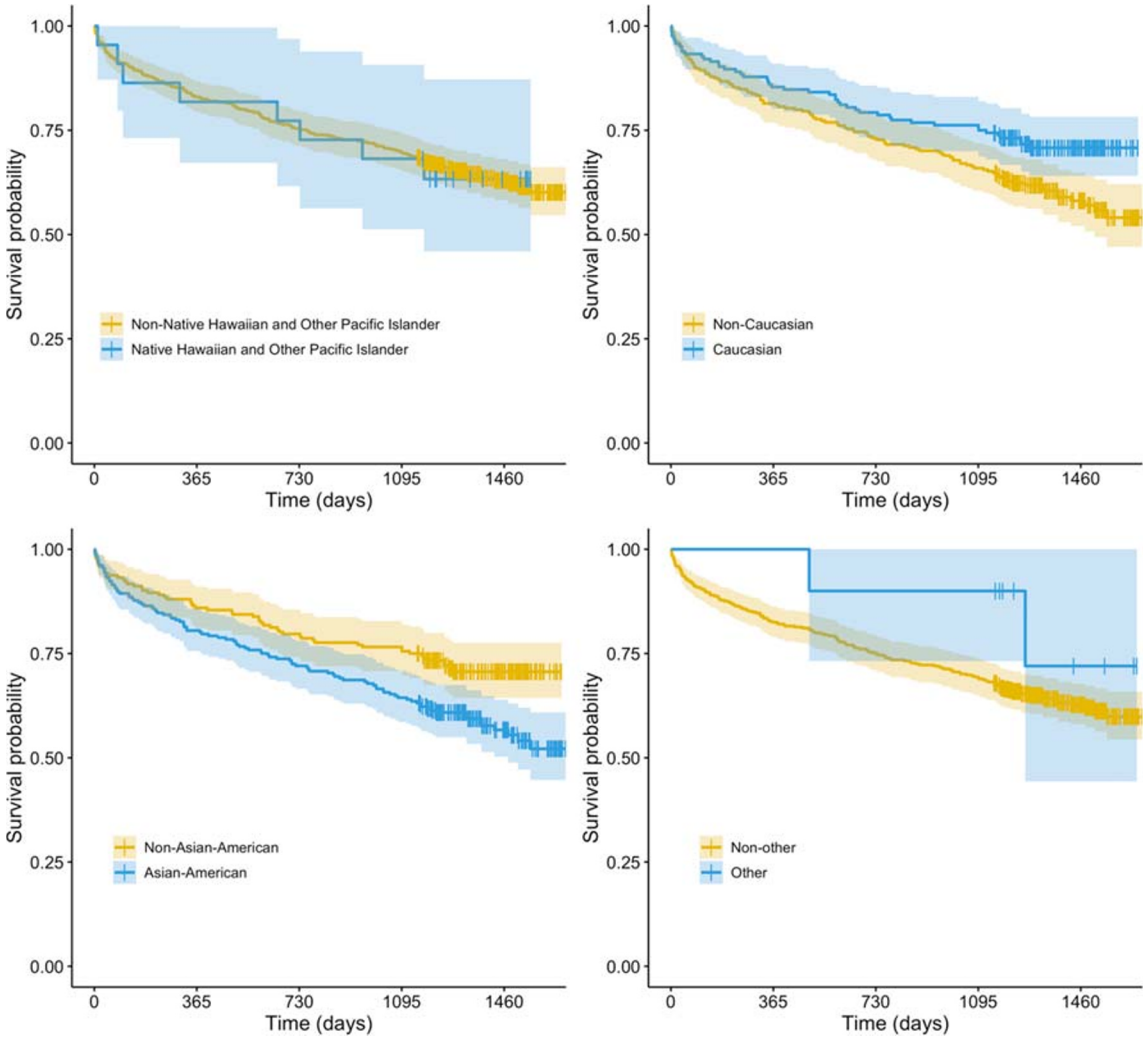

Fig. 2 Kaplan-Meier curve by each racial group

regression showed that older age, lower BMI, and increased CCI score to be associated with increased risk for mortality.

Long-term mortality (1-year, 2-year, and 3-year mortality)

Multivariable logistic regression (Table 3) showed that older age, male sex, lower BMI, and higher CCI scores were associated with increased mortality at 1, 2, and 3 years after admission for hip fracture.

Proportional hazards regression analysis

Through proportional hazards regression analysis (Table 4), factors associated with increased mortality included increased age (hazard ratio (HR) = 1.06; $p < 0.001$), higher CCI score (HR = 1.30; $p < 0.001$), and primary payer status-Medicare/Medicaid (HR = 3.78; $p = 0.021$) were associated with increased mortality. Higher BMI (HR = 0.94; $p = 0.002$) and females sex (HR = 0.54; $p < 0.001$) were associated with decreased mortality. Table 5 provides additional information showing number of patients at risk and those who died at various intervals.

Interaction between gender and CCI

In our study, males were found to have high mortality. Prior studies have suggested that the higher CCI at baseline may explain this difference. We investigated our models including the gender and CCI interaction term. CCI was not a significant factor across all the models.

Other outcomes-charges and total length of stay

The average length of stay was 6.7 days (standard deviation (SD) 6.4). The average cost per admission was $14,442.20 (SD $10,434.26). The median of cost per admission was $12,015 (interquartile range $16,028–$9667).

Table 3 Multivariable logistic regression of mortality

	30-day mortality		90-day mortality		1-year mortality		2-year mortality		3-year mortality	
	OR (95%CI)	*p*	OR (95%CI)	*p*	OR (95%CI)	*p*	OR (95%CI)	*p*	OR (95%CI)	*p*
Age	1.11 (1.05, 1.20)*	0.002	1.10 (1.05, 1.16)*	< 0.001	1.07 (1.03, 1.10)*	< 0.001	1.07 (1.04, 1.11)*	< 0.001	1.07 (1.04, 1.10)*	< 0.001
Female (ref: male)	0.25 (0.08, 072)*	0.011	0.49 (0.22, 1.10)	0.080	0.49 (0.26, 0.90)*	0.022	0.44 (0.25, 0.76)*	0.003	0.45 (0.27, 0.76)*	0.003
Race										
Asian-American	0.55 (0.19, 1.63)	0.273	0.71 (0.17, 4.07)	0.663	1.55 (0.45, 6.58)	0.515	1.18 (0.41, 3.79)	0.763	1.41 (0.52, 4.19)	0.516
Caucasian	N/A‡	N/A‡	0.80 (0.18, 4.66)	0.784	1.70 (0.47, 7.44)	0.445	1.37 (0.46, 4.52)	0.586	1.27 (0.45, 3.89)	0.666
Body mass index	0.92 (0.79, 1.05)	0.235	0.88 (0.79, 0.96)*	0.009	0.89 (0.82, 0.95)*	0.002	0.89 (0.83, 0.95)*	<0.001	0.90 (0.84, 0.95)*	<0.001
Treatment facility (ref: A)										
B	N/A‡	N/A‡	N/A‡	N/A‡	1.03 (0.51, 2.09)	0.941	1.11 (0.60, 2.05)	0.748	1.00 (0.56, 1.78)	0.996
C	N/A‡	N/A‡	N/A‡	N/A‡	0.93 (0.42, 1.99)	0.847	0.88 (0.45, 1.72)	0.718	0.83 (0.43, 1.55)	0.552
Charlson comorbidity index	1.18 (0.92, 1.45)	0.143	1.30 (1.10, 1.53)*	0.001	1.53 (1.34, 1.78)*	< 0.001	1.45 (1.28, 1.66)*	< 0.001	1.47 (1.30, 1.68)*	< 0.001
Length of stay	0.98 (0.86, 1.05)	0.759	1.02 (0.97, 1.06)	0.275	1.02 (0.99, 1.07)	0.229	1.03 (1.00, 1.08)	0.121	1.02 (0.99, 1.07)	0.281
Femoral neck fractures	N/A‡	N/A‡	0.75 (0.28, 2.14)	0.578	0.79 (0.30, 2.19)	0.644	0.70 (0.29, 1.74)	0.429	0.65 (0.28, 1.52)	0.312
Intertrochanteric fractures	0.34 (0.08, 1.13)	0.109	0.46 (0.15, 1.42)	0.166	0.57 (0.21, 1.60)	0.276	0.86 (0.36, 2.14)	0.739	0.76 (0.33, 1.77)	0.518
No surgery	N/A‡	N/A‡	N/A‡	N/A‡	1.18 (0.40, 3.29)	0.755	1.03 (0.39, 2.64)	0.948	0.89 (0.35, 2.21)	0.804

Each race group is its own dummy variable and not mutually exclusive

Native Hawaiian and Other Pacific Islander, other (race), and insurance variables were not included in the table due to low frequency throughout the 5 models

* $p < 0.05$

‡ Not included in the model due to low frequencies

Discussion

Our study reports mortality after admission for osteoporotic hip fracture in a large healthcare system in Hawai'i. The 1-year mortality after admission for hip fracture was approximately 17%. To our knowledge, no prior studies have investigated the mortality after hip fracture in Hawai'i. Our study highlights the importance of efforts to focus on osteoporosis care in Hawai'i and provides crucial epidemiological information about hip fractures in Hawai'i. Additionally, this contemporary information for mortality of hip fractures highlights the fact that hip fractures remain a high-risk condition that are costly and pose a significant burden to the healthcare system. Factors associated with mortality included increased age, male sex, higher CCI score, primary insurance status-Medicare/Medicaid, and lower BMI.

The mortality in our study is consistent with prior studies. Most recently in 2017, a study in the USA using the Kaiser Permanente database described a 1-year mortality post-hip fracture of 21%, with 30-day mortality at 6%, and 90-day mortality at 11% [20]. A national population-based study in Taiwan of 5442 patients who had hip fracture surgery from 2000 to 2009 showed that overall mortality was 16.8% [21]. An observational study of 43,830 patients attending public hospitals in Hong Kong who underwent surgery for geriatric hip fracture from 2000 to 2011 showed a mortality of 16.8% [22]. Many local studies in Europe and South America have reported high mortality after hip fracture ranging from 16 to 34.8% [23–25]. In a meta-analysis by Haentjens et al., patients with hip fractures were found to have a five- to eightfold increased risk of mortality in the first 3 months after hip fracture, with excess mortality decreasing 2 years after fracture. Even at 10 years of follow-up, excess mortality risk did not return to the rate of age-matched control participants [26].

The reasons for increased mortality after admission for osteoporotic hip fracture remain unclear, but several different factors likely play a role [27]. Hip fractures by themselves are not the direct cause of death, but rather it is the cascade of events that results from the fracture and subsequent immobility that places a person at higher risk for death [27]. Hip fractures lead to hospitalization and immobility, increasing the risk of stroke, myocardial infarction, heart failure, and pneumonia [28]. Stroke, myocardial infarction, heart failure, and pneumonia may also be postoperative complications associated with hip surgery [26]. Cardiovascular disease and pneumonia have been found to be the causes of death in hip fracture patients [28, 29].

In our study, the CCI was used to estimate the patient's comorbidity load. We found that a higher CCI was associated with an increased risk of mortality. Several prior studies have shown a similar association between a higher comorbidity load and mortality after hip fracture [30–32]. The comorbidity load of a patient is an unmodifiable mortality risk predictor

Table 4 Multivariable proportional hazards regression model

	Death~time (censored on 07/25/2019 for those date of death not available)	
	Hazard ratio (95% CI)	*p*
Age, years	1.06 (1.03, 1.08)*	< 0.001
Female (ref: male)	0.54 (0.38, 0.76)*	< 0.001
Race		
Native Hawaiian and Other Pacific Islander	1.60 (0.38, 6.80)	0.521
Asian-American	1.32 (0.30, 5.90)	0.713
Caucasian	1.36 (0.30, 6.08)	0.689
Other	0.51 (0.07, 3.92)	0.516
Body mass index	0.94 (0.90, 0.98)*	0.002
Treatment facility (ref: A)		
B	0.80 (0.54, 1.19)	0.277
C	0.93 (0.61, 1.43)	0.739
Medicare/Medicaid (ref: private)	3.78 (1.22, 11.71)*	0.021
Charlson comorbidity index	1.30 (1.22, 1.40)*	< 0.001
Length of stay, days	1.02 (1.00, 1.04)	0.082
Femoral neck fractures	1.31 (0.71, 2.41)	0.386
Intertrochanteric fractures	1.11 (0.60, 2.06)	0.735
No surgery	1.62 (0.86, 3.05)	0.135

Each race group is its own dummy variable and not mutually exclusive

* $p < 0.05$

[30]. However, our study supports the notion that the comorbidity load is an essential piece of information to be obtained because it may be helpful to physicians in determining the prognosis of hip fracture patients, a critical component of perioperative counseling.

Increased osteoporotic hip fracture mortality has been associated with frailty (defined as a vulnerability to adverse health outcomes due to a decline in late-life across multiple physiologic systems) [33, 34]. The prevalence of frailty increases with age [35]. A high CCI is also associated with frailty [36]. Frailty may have been present before the hip fracture or caused by a hip fracture. It is unclear if frailty is present before the admission, developed after admission, or possibly concomitantly contributed to increased excess mortality. Further studies are needed to clarify this relationship [26]. Lower BMI has been associated with increased mortality after fracture in prior studies, and also in other chronic conditions [37]. However, the reasons for the protective effect of obesity and increased weight (i.e., the obesity paradox) remain unclear [37]. Some authors have suggested that obesity may be protective against frailty, while other authors have suggested methodical and noncausal explanations, including reverse causation [37, 38]. Further studies are needed to delineate this association.

In our study, men were approximately twice as likely to die as compared to women after fracture, consistent with prior studies showing that men have greater mortality post-fracture [26, 39–41]. There could be several reasons to explain this. Wehren et al. previously reported that increased mortality was related to increased risk of infections (pneumonia, influenza, and septicemia) in men. Men are more likely to have comorbid conditions at that time of fracture. However, some studies have suggested that a difference in comorbidities may not account for the mortality differences between men and women [39]. In our study, we investigated our models to include the gender and CCI interaction terms. CCI was not a

Table 5 Cumulative deaths over time

Time (days)	0	30	90	365 (1 year)	730 (2 years)	1095 (3 years)	1460 (4 years)
Number at risk	428	410	391	355	323	299	107
Cumulative number of censored	0	0	0	0	0	0	169
Cumulative death	0	18	37	73	105	129	152

significant factor across all models. In our study, the risk of death of individuals with primary insurance status of Medicare/Medicaid was 3.8 times higher the individuals with primary insurance status of private insurance. This is consistent with prior studies [42] and could be attributed to differences in referral network access, as well as treatment patterns of providers due to insurance differences [43].

Our study has strengths and limitations. Firstly, our study is the first study to report mortality after osteoporotic hip fracture admission in Hawai'i. This provides invaluable data for the understanding burden of disease of osteoporosis and hip fractures in Hawai'i. The limitations of our study include errors, inconsistencies, and omissions due to the retrospective nature of our study, with data collected from electronic medical records. We may not have been able to identify patient deaths if the death notices were not reported online or if the information was not available on electronic medical records. Therefore, the mortality of this study may be underestimated. Due to inclusion criteria requiring at least 1-year of follow-up, there is possibility of missing patients who died after discharge from the hospital but did not have at least 1 year of follow-up, leading to underestimation of mortality. We complemented chart review with the search for death notices online, which is a novel approach that can help increase the validity of mortality estimates. Medical chart review is limited due to reliance on notifications received from involved parties that the patient is deceased. Hospital records only report a terminal event if the event occurred in the hospital. By using death notices online, we were able to track the vital status of patients who otherwise would have been lost to follow-up [16]. Secondly, we were not able to determine the cause of death for patients admitted for hip fractures because we did not have access to certificates of death. Furthermore, the accuracy of causes of death from certificates of death is uncertain [44]. The design of our study may limit our ability to investigate this, and future prospective studies may be more useful in determining specific causes of death after hip fracture. Thirdly, we do not have a control group for comparison of mortality.

In conclusion, osteoporotic hip fractures in Hawai'i are associated with high mortality. Increased age, male sex, higher CCI score, primary insurance status-Medicare/Medicaid, and lower BMI were associated with increased mortality. This reflects the life-threatening danger of sustaining a hip fracture and prompts a focus on the importance of prevention of osteoporotic fractures and the improvement of post-fracture care of patients.

Funding The biostatisticians are partially supported by the National Institutes of Health grants: U54MD00760131 and U54GM104944. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH.

Data availability Data are available on request due to privacy/ethical restrictions.

Compliance with ethical standards

Conflict of interest None.

References

1. Nguyen ET, Posas-Mendoza T, Siu AM, Ahn HJ, Choi SY, Lim SY (2018) Low rates of osteoporosis treatment after hospitalization for hip fracture in Hawaii. Osteoporos Int 29(8):1827–1832. https://doi.org/10.1007/s00198-018-4553-2
2. Lewiecki EM, Wright NC, Curtis JR et al (2018) Hip fracture trends in the United States, 2002 to 2015. Osteoporos Int 29(3):717–722. https://doi.org/10.1007/s00198-017-4345-0
3. Centers for Disease Control and Prevention National Center for Injury Prevention and Control. Hip fractures among older adults 2016 [Available from: https://www.cdc.gov/homeandrecreationalsafety/falls/adulthipfx.html accessed October 19th 2019
4. Schnell S, Friedman SM, Mendelson DA, Bingham KW, Kates SL (2010) The 1-year mortality of patients treated in a hip fracture program for elders. Geriatr Orthop Surg Rehabil 1(1):6–14. https://doi.org/10.1177/2151458510378105
5. Downey C, Kelly M, Quinlan JF (2019) Changing trends in the mortality rate at 1-year post hip fracture - a systematic review. World J Orthop 10(3):166–175. https://doi.org/10.5312/wjo.v10.i3.166
6. Brauer CA, Coca-Perraillon M, Cutler DM et al (2009) Incidence and mortality of hip fractures in the United States. JAMA 302(14):1573–1579. https://doi.org/10.1001/jama.2009.1462
7. Kaneshiro B, Geling O, Gellert K et al (2011) The challenges of collecting data on race and ethnicity in a diverse, multiethnic state. Hawaii Med J 70(8):168–171
8. Dickson M, Plauschinat CA (2008) Racial differences in medication compliance and healthcare utilization among hypertensive Medicaid recipients: fixed-dose vs free-combination treatment. Ethn Dis 18(2):204–209 published Online First: 2008/05/30
9. Sterling RS (2011) Gender and race/ethnicity differences in hip fracture incidence, morbidity, mortality, and function. Clin Orthop Relat Res 469(7):1913–1918. https://doi.org/10.1007/s11999-010-1736-3
10. Sheehan KJ, Sobolev B, Villan Villan YF et al (2017) Patient and system factors of time to surgery after hip fracture: a scoping review. BMJ Open 7(8):e016939. https://doi.org/10.1136/bmjopen-2017-016939
11. Tanne JH (2007) Is Wisconsin or Hawaii the healthiest US state? BMJ 334(7607):1293. https://doi.org/10.1136/bmj.39251.380428.DB published Online First: 2007/06/23
12. Metcalfe D, Zogg CK, Judge A, Perry DC, Gabbe B, Willett K, Costa ML (2019) Pay for performance and hip fracture outcomes: an interrupted time series and difference-in-differences analysis in England and Scotland. Bone Joint J 101-B(8):1015–1023. https://doi.org/10.1302/0301-620X.101B8.BJJ-2019-0173.R1
13. Hawaii Pacific Health. Hawaii Pacific Health-About Us 2017 [Available from: https://www.hawaiipacifichealth.org/about-us/overview/ accessed November 20th 2017
14. de Groot V, Beckerman H, Lankhorst GJ et al (2003) How to measure comorbidity. A critical review of available methods. J Clin Epidemiol 56(3):221–229. https://doi.org/10.1016/s0895-4356(02)00585-1
15. Charlson ME, Pompei P, Ales KL, MacKenzie CR (1987) A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis 40(5):373–383. https://doi.org/10.1016/0021-9681(87)90171-8

16. Soowamber ML, Granton JT, Bavaghar-Zaeimi F, Johnson SR (2016) Online obituaries are a reliable and valid source of mortality data. J Clin Epidemiol 79:167–168. https://doi.org/10.1016/j.jclinepi.2016.05.012
17. Stephens KU Sr, Grew D, Chin K, Kadetz P, Greenough PG, Burkle FM Jr, Robinson SL, Franklin ER (2007) Excess mortality in the aftermath of Hurricane Katrina: a preliminary report. Disaster Med Public Health Prep 1(1):15–20. https://doi.org/10.1097/DMP.0b013e3180691856
18. Boak MB, M'Ikanatha NM, Day RS et al (2008) Internet death notices as a novel source of mortality surveillance data. Am J Epidemiol 167(5):532–539. https://doi.org/10.1093/aje/kwm331
19. Lim SY, Lu N, Oza A, Fisher M, Rai SK, Menendez ME, Choi HK (2016) Trends in gout and rheumatoid arthritis hospitalizations in the United States, 1993-2011. JAMA 315(21):2345–2347. https://doi.org/10.1001/jama.2016.3517
20. Okike K, Chan PH, Paxton EW (2017) Effect of surgeon and hospital volume on morbidity and mortality after hip fracture. J Bone Joint Surg Am 99(18):1547–1553. https://doi.org/10.2106/JBJS.16.01133
21. Lee TC, Ho PS, Lin HT et al (2017) One-year readmission risk and mortality after hip fracture surgery: a national population-based study in Taiwan. Aging Dis 8(4):402–409. https://doi.org/10.14336/AD.2016.1228
22. Liu SK, Ho AW, Wong SH (2017) Early surgery for Hong Kong Chinese elderly patients with hip fracture reduces short-term and long-term mortality. Hong Kong Med J 23(4):374–380. https://doi.org/10.12809/hkmj165005
23. Medin E, Goude F, Melberg HO, Tediosi F, Belicza E, Peltola M, on behalf of the EuroHOPE study group (2015) European regional differences in all-cause mortality and length of stay for patients with hip fracture. Health Econ 24(Suppl 2):53–64. https://doi.org/10.1002/hec.3278
24. Kristensen MT, Kehlet H (2018) The basic mobility status upon acute hospital discharge is an independent risk factor for mortality up to 5 years after hip fracture surgery. Acta Orthop 89(1):47–52. https://doi.org/10.1080/17453674.2017.1382038
25. Guerra MT, Viana RD, Feil L et al (2017) One-year mortality of elderly patients with hip fracture surgically treated at a hospital in Southern Brazil. Rev Bras Ortop 52(1):17–23. https://doi.org/10.1016/j.rboe.2016.11.006
26. Haentjens P, Magaziner J, Colon-Emeric CS et al (2010) Meta-analysis: excess mortality after hip fracture among older women and men. Ann Intern Med 152(6):380–390. https://doi.org/10.7326/0003-4819-152-6-201003160-00008
27. Cauley JA (2013) Public health impact of osteoporosis. J Gerontol A Biol Sci Med Sci 68(10):1243–1251. https://doi.org/10.1093/gerona/glt093
28. Boereboom FT, Raymakers JA, Duursma SA (1992) Mortality and causes of death after hip fractures in The Netherlands. Neth J Med 41(1–2):4–10
29. von Friesendorff M, McGuigan FE, Wizert A et al (2016) Hip fracture, mortality risk, and cause of death over two decades. Osteoporos Int 27(10):2945–2953. https://doi.org/10.1007/s00198-016-3616-5
30. Cher EWL, Allen JC, Howe TS, Koh JSB (2019) Comorbidity as the dominant predictor of mortality after hip fracture surgeries. Osteoporos Int 30(12):2477–2483. https://doi.org/10.1007/s00198-019-05139-8
31. Neuhaus V, King J, Hageman MG, Ring DC (2013) Charlson comorbidity indices and in-hospital deaths in patients with hip fractures. Clin Orthop Relat Res 471(5):1712–1719. https://doi.org/10.1007/s11999-012-2705-9
32. Lunde A, Tell GS, Pedersen AB, Scheike TH, Apalset EM, Ehrenstein V, Sørensen HT (2019) The role of comorbidity in mortality after hip fracture: a nationwide Norwegian study of 38,126 women with hip fracture matched to a general-population comparison cohort. Am J Epidemiol 188(2):398–407. https://doi.org/10.1093/aje/kwy251
33. Fried LP, Tangen CM, Walston J, Newman AB, Hirsch C, Gottdiener J, Seeman T, Tracy R, Kop WJ, Burke G, McBurnie MA (2001) Frailty in older adults: evidence for a phenotype. J Gerontol A Biol Sci Med Sci 56(3):M146–M156. https://doi.org/10.1093/gerona/56.3.m146
34. Vasu BK, Ramamurthi KP, Rajan S, George M (2018) Geriatric patients with hip fracture: frailty and other risk factors affecting the outcome. Anesth Essays Res 12(2):546–551. https://doi.org/10.4103/aer.AER_61_18
35. Song X, Mitnitski A, Rockwood K (2010) Prevalence and 10-year outcomes of frailty in older adults in relation to deficit accumulation. J Am Geriatr Soc 58(4):681–687. https://doi.org/10.1111/j.1532-5415.2010.02764.x
36. Boeckxstaens P, Vaes B, Legrand D, Dalleur O, de Sutter A, Degryse JM (2015) The relationship of multimorbidity with disability and frailty in the oldest patients: a cross-sectional analysis of three measures of multimorbidity in the BELFRAIL cohort. Eur J Gen Pract 21(1):39–44. https://doi.org/10.3109/13814788.2014.914167
37. Prieto-Alhambra D, Premaor MO, Aviles FF et al (2014) Relationship between mortality and BMI after fracture: a population-based study of men and women aged >/=40 years. J Bone Miner Res 29(8):1737–1744. https://doi.org/10.1002/jbmr.2209
38. Sheehan KJ, O'Connell MD, Cunningham C et al (2013) The relationship between increased body mass index and frailty on falls in community dwelling older adults. BMC Geriatr 13:132. https://doi.org/10.1186/1471-2318-13-132
39. Wehren LE, Hawkes WG, Orwig DL, Hebel JR, Zimmerman SI, Magaziner J (2003) Gender differences in mortality after hip fracture: the role of infection. J Bone Miner Res 18(12):2231–2237. https://doi.org/10.1359/jbmr.2003.18.12.2231
40. Jacobsen SJ, Goldberg J, Miles TP, Brody JA, Stiers W, Rimm AA (1992) Race and sex differences in mortality following fracture of the hip. Am J Public Health 82(8):1147–1150. https://doi.org/10.2105/ajph.82.8.1147
41. Penrod JD, Litke A, Hawkes WG, Magaziner J, Doucette JT, Koval KJ, Silberzweig SB, Egol KA, Siu AL (2008) The association of race, gender, and comorbidity with mortality and function after hip fracture. J Gerontol A Biol Sci Med Sci 63(8):867–872. https://doi.org/10.1093/gerona/63.8.867
42. Daniel VT, Ayturk D, Ward DV, McCormick BA, Santry HP (2019) The influence of payor status on outcomes associated with surgical repair of upper gastrointestinal perforations due to peptic ulcer disease in the United States. Am J Surg 217(1):121–125. https://doi.org/10.1016/j.amjsurg.2018.06.025
43. Spencer CS, Gaskin DJ, Roberts ET (2013) The quality of care delivered to patients within the same hospital varies by insurance type. Health Aff (Millwood) 32(10):1731–1739. https://doi.org/10.1377/hlthaff.2012.1400
44. Mieno MN, Tanaka N, Arai T, Kawahara T, Kuchiba A, Ishikawa S, Sawabe M (2016) Accuracy of death certificates and assessment of factors for misclassification of underlying cause of death. J Epidemiol 26(4):191–198. https://doi.org/10.2188/jea.JE20150010