European Journal of Orthopaedic Surgery & Traumatology (2019) 29:1253–1261
https://doi.org/10.1007/s00590-019-02438-y

ORIGINAL ARTICLE • HIP - ARTHROPLASTY

Surgical complications associated with congestive heart failure in elderly patients following primary hip hemiarthroplasty for femoral neck fractures

Ryan Lee[1] · Danny Lee[1] · Nikhil B. Gowda[1] · William V. Probasco[2] · George Ibrahim[2] · David P. Falk[3] · Rajeev Pandarinath[2]

Received: 7 November 2018 / Accepted: 11 April 2019 / Published online: 30 April 2019

Abstract

Introduction Although there are reports of the impact of congestive heart failure (CHF) on total knee arthroplasty and total hip arthroplasty, there is a lack of literature analyzing CHF in hip hemiarthroplasty (HHA) procedures. The main objective of this study was to evaluate the effect of CHF on risks for complications following HHA for the treatment of FNF.

Methods The ACS-NSQIP database was queried for all patients who had undergone HHA from 2005 to 2016. Patients were propensity-matched without replacement in a 1:1 manner based on age and gender. Pearson's Chi squared tests and Fischer's exact tests were utilized to compare differences in demographics, comorbidities, and complication rates. Multivariate logistic regression analyses were used to assess the impact of CHF as an independent risk factor for postoperative complications.

Results A propensity-matched cohort of 537 (4.24%) non-CHF patients was generated in order to analyze differences between the two cohorts. CHF was found to be a significant independent risk factor for pneumonia ($p = 0.003$), progressive renal insufficiency ($p = 0.040$), myocardial infarctions ($p = 0.050$), extended length of stay (≥ 5 days) ($p < 0.001$), and mortality ($p < 0.001$).

Conclusion This study has established CHF as an independent risk factor for various postoperative complications following HHA for the treatment of FNF. Although orthopedic surgeons may decline to perform elective procedures on CHF patients, FNFs require urgent surgical intervention. Therefore, it is important to be aware of various increased risks of certain complications in this subset patient population.

Keywords Congestive heart failure · Hip hemiarthroplasty · Complications · Pneumonia · Mortality

Introduction

Congestive heart failure (CHF) is a complex medical syndrome. It is defined as the heart's inability to adequately fill with blood and/or eject blood to perfuse the systemic circulation in the diastolic and systolic phases, respectively [1–3]. Due to the failing heart's impaired function throughout the cardiac contraction cycle, the cardiac output (CO) produced is suboptimal in meeting the metabolic demands of the rest of the body [2]. Consequentially, characteristic symptoms of CHF including dyspnea, fatigue, and edema secondary to fluid retention can occur [4]. CHF can be caused by a multitude of structural and functional anomalies. It can also result from toxic insults including myocardial ischemia, chronic hypertension, valvular dysfunction, diabetes, pulmonary hypertension, alcohol abuse, and cocaine abuse [5]. Affecting nearly 26 million people globally, the incidence and prevalence of CHF continues to increase as medical advancements have allowed patients with CHF to live longer lives [6, 7]. In the USA alone, there is a projected 127% increase in CHF-related healthcare expenditures by 2030 [7]. As the societal burden of CHF continues to grow, it is critical that we

✉ Rajeev Pandarinath
rpandarinath@mfa.gwu.edu

1 The George Washington University School of Medicine and Health Sciences, The George Washington University, 2300 I St NW, Washington, DC 20052, USA

2 Department of Orthopaedic Surgery, The George Washington University, 2300 M Street NW, Washington, DC 20037, USA

3 Department of Orthopaedic Surgery, Hospital of the University of Pennsylvania, 3737 Market Street, Philadelphia, PA 19104, USA

understand its impact on other common conditions faced by the aging population.

Just as CHF is more prevalent in the elderly population, so too are femoral neck fractures (FNFs). FNFs are a huge burden to healthcare systems specifically due to extended hospital courses, rehabilitation, and multiple complications that can be involved [8, 9]. It is important to consider each comorbidity in geriatric patients presenting with hip fractures. Specifically, cardiac, pulmonary, and renal conditions are associated with higher rates of perioperative complications—previous studies have examined the impact of CHF on other orthopedic procedures such as total knee arthroplasty (TKA) and total hip arthroplasty (THA) [10, 11]. However, the impacts of CHF on hip hemiarthroplasty (HHA) in the setting of FNF have yet to be elucidated. Although studies examining the effects of CHF on TKA/THA complication rates have been explored, these total joint arthroplasties are commonly done as elective procedures that may allow for greater time and preoperative optimization prior to the procedure. However, preoperative optimization of patients in CHF in the setting of FNF with acceptable life expectancies is largely not possible due to the urgency of the required surgical intervention. As HHA can be used in the treatment for FNFs, analyzing the effects of CHF on complication rates following HHA may better allow surgeons to care for patients in the postoperative period by anticipating certain complications following HHA to minimize patient mortality and maximize successful outcomes. Through an understanding of relevant complications and their associated preoperative precautionary measures, surgeons can help mitigate the economic burden associated with unanticipated surgical complications in an already vulnerable population of elderly patients.

The main objectives of the current study are to: (1) elucidate the prevalence of specific demographic factors and preoperative comorbidities in HHA for FNFs in patients with CHF, (2) analyze differences in patient characteristics and administrative/operation-specific parameters, and (3) establish the impact of CHF on the risk for experiencing perioperative and postoperative complications in a vulnerable population of elderly patients. We hypothesize that patients who have had a history of CHF will present with higher rates of comorbidities and also be at an increased risk for various adverse events, such as reoperation, readmission, and other medical/surgical complications related to HHA in the treatment of FNF. By establishing these associations with CHF and specific complications, orthopedic surgeons can better prepare their patients for surgery to reduce economic costs, guide healthcare facilities in preparing for specific adverse events, and more importantly, help surgeons decide whether to operate in this vulnerable patient population after weighing the risks and benefits with the patients in question.

Materials and methods

Patient cohort selection

The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database was queried for patients who had undergone primary hemiarthroplasty procedures of the hip for femoral neck fractures from 2005 to 2016. The ACS-NSQIP database is a multi-institutional clinical registry of 5,608,708 surgical patient files provided by 680 participating institutions [12]. This study was exempt from institutional review board approval as it utilized a publicly available database. The database maintains comprehensive medical profiles for each patient undergoing a surgical procedure. Patients who had undergone HHA were analyzed to establish significant associations between a history of CHF and complications following their procedure. The patients were isolated by Current Procedure Terminology (CPT) codes limited to 27125 which denotes a femoral component hemiarthroplasty for acquired, congenital, and/or degenerative disease. A total of 14,695 patients who had undergone HHA were isolated and included in this current retrospective study. Patients who had undergone a primary THA (CPT code 27130) or related revisional procedures to a previous hip arthroplasty (CPT codes 27134, 27137, and 27138) were excluded from this analysis. These patients were then filtered specifically for femoral fracture diagnoses using International Classification of Disease (ICD)-9 codes of 820.00–820.19, 820.8, 820.9 or an ICD-10 code of S72.000–S72.099. Other diagnoses, such as, osteoarthritis or rheumatoid arthritis, were excluded. All included patients were ≥ 18 years old with complete medical and surgical histories provided by the NSQIP database for analysis. These fracture patients were stratified into two cohorts based on the presence or absence of preoperative, "congestive heart failure within 30 days prior to the operation." [12].

Variables

The ACS-NSQIP database maintains information on 274 variables related to each individual patient's demographic and medical profile [13]. In maintaining details about each patient's history, it allows healthcare providers at participating institutions to study extremely large cohorts of patients to test for significant differences in the prevalence of specific morbidities, as well as analyze risk associations between characteristic patient profiles and adverse events following surgery. The variables are categorized as demographic factors, preoperative comorbidities, laboratory values from blood workup, and perioperative and postoperative outcomes in providing great insight into better stratifying risk levels for individual patients.

Demographic characteristics that were analyzed as a part of this current study include age, sex, race, and BMI, further stratified into five weight classes; these factors were analyzed for the purpose of providing holistic analyses from a population standpoint. Patients' preoperative comorbidities were assessed in order to gain better insight into the health status of each patient including obesity, diabetes mellitus, smoking status, alcohol use, dyspnea, ventilator dependence, chronic obstructive pulmonary disease (COPD), ascites, dialysis dependence, disseminated cancer, open wounds/wound infections, steroid use for chronic conditions, significant weight loss (> 10% body weight in the past 6 months), hematologic disorders (i.e., Vitamin K deficiency, hemophilias, thrombocytopenia) [13], blood transfusions (≥ 1 unit of RBCs within 72 h prior to the specific operation), systemic sepsis, and preoperative functional status (i.e., completely dependent, functionally dependent, and independent). These comorbidities were assessed for significant differences between the two cohorts of HHA patients to evaluate the overall health status of patients in these two samples. Laboratory values for important biomarkers were also reported in the NSQIP database and analyzed in this retrospective study; serum concentrations of sodium, blood urea nitrogen (BUN), creatinine, albumin, white blood cell count, hematocrit, and platelet count were evaluated.

Operative variables, such as American Society of Anesthesiologists (ASA) class, type of anesthesia administered, total operative time, total hospital stay length, time to discharge, and discharge destination, pertaining to the respective procedure in each patient were also studied to gain a better understanding of the differences in surgical complications.

Notable 30-day postoperative complications included in this study are superficial incisional surgical site infections (SSI), deep incisional SSI, organ/space SSI, wound dehiscence, pneumonia, unplanned intubation, pulmonary embolisms, ventilator dependence for > 48 h, progressive renal insufficiency, acute renal failure, urinary tract infections (UTI), strokes, cardiac arrest requiring cardiopulmonary resuscitation (CPR), myocardial infarctions (MIs), deep venous thromboembolisms (DVTs), postoperative blood transfusions, septic shock, systemic sepsis, return to the operating room (OR), extended length of stay (LOS) following the operation (≥ 5 days), unplanned readmission within 30 days, and 30-day mortality.

Statistical analysis

Univariate analyses were utilized when testing for significant differences in the prevalence of certain characteristics between the two cohorts—CHF and non-CHF patients. Patients were matched without replacement based on age and gender using propensity matching in a 1:1 manner in order to reduce selection bias. Demographic factors, comorbidities, and postoperative complications were all analyzed using Pearson's Chi-squared tests for categorical variables, which are expressed as number and frequencies of occurrence. Fischer's exact test was also utilized in analyzing categorical variables when there were expected cell sizes less than five. Continuous variables, such as age and laboratory values, were analyzed using independent two-sample t-tests in comparing the mean values of each variable between the two cohorts. Continuous variables are expressed as mean values with respective standard deviations. All statistical findings from the univariate analyses were considered significant when p values were less than or equal to 0.05.

This retrospective study further analyzed perioperative and postoperative complications through multivariate regression analyses. Multivariate logistic regression models were utilized in order to assess whether CHF independently increased the risk for certain complications. These multivariate regression models were generated by controlling for significant demographic factors and preoperative comorbidities for the purpose of examining CHFs independent association with increased risk levels for adverse events. This multivariate analysis controlled for age, sex, diabetes mellitus, dyspnea, ventilator dependence, COPD, dialysis dependence, open wound/wound infection, steroid use, hematologic disorders, preoperative blood transfusions, systemic sepsis, and preoperative functional status to calculate odds ratios (OR) with 95% confidence intervals (CI) for each individual complication. All multivariate regression models yielding p values ≤ 0.05 were considered significant. All statistical analyses were performed using the IBM® SPSS® Statistics version 25 software. (IBM Corporation, Armonk, NY).

Results

By querying the ACS-NSQIP database, 12,676 patients who had undergone HHA for fractures between 2005 and 2016 were isolated, of which 537 (4.24%) had a previous history of CHF within 30 days prior to their hemiarthroplasty procedure. A propensity-matched cohort of 537 non-CHF patients was generated in order to analyze differences between the two cohorts. There were no significant differences in their mean age ($p = 0.592$), sex distribution ($p = 0.804$), race distribution ($p = 0.054$), or body mass index ($p = 0.135$; Table 1).

In terms of preoperative comorbidities between the two cohorts of patients, significant differences were observed in a variety of disease states. Patients with a history of CHF had significantly higher rates of diabetes mellitus ($p = 0.004$),

Table 1 Demographics of patients

	Control	%	CHF[a]	%	*p* value
Demographics	($n=537$)		($n=537$)		
Age (mean ± SD)[b]	83.15 ± 8.369		83.69 ± 8.607		0.592
Sex					0.804
Female	316	58.85	312	58.10	
Male	221	41.15	225	41.90	
Race					0.054
Asian or Pacific Islander	20	3.72	8	1.49	
Black or African-American	22	4.10	19	3.54	
White	382	71.14	392	73.00	
Body mass index (kg/m^2)					0.135
Normal (< 25.0)	286	53.26	265	49.35	
Overweight (25.0–29.9)	142	26.44	129	24.02	
Class I (30.0–34.9)	30	5.59	50	9.31	
Class II (35.0–39.9)	6	1.12	9	1.68	
Class III (> 40.0)	5	0.93	6	1.12	
Preoperative comorbidities					
Diabetes mellitus					**0.004**
No diabetes mellitus	454	84.54	417	77.65	
Non-insulin dependent	56	10.43	67	12.48	
Insulin dependent	27	5.03	53	9.87	
Smoke	52	9.68	56	10.43	0.685
Alcohol	3	0.56	0	0.00	0.249
Dyspnea					**< 0.001**
No dyspnea	497	92.55	399	74.30	
Moderate exertion	34	6.33	107	19.93	
At rest	6	1.12	31	5.77	
Ventilator dependence	0	0.00	7	1.30	**0.015**
COPD[c]	50	9.31	158	29.42	**< 0.001**
Ascites	1	0.19	4	0.74	0.374
Dialysis dependence	11	2.05	25	4.66	**0.018**
Disseminated cancer	8	1.49	8	1.49	1.000
Wound infection	28	5.21	51	9.50	**0.007**
Steroid use	19	3.54	45	8.38	**0.001**
Weight loss	6	1.12	9	1.68	0.435
Bleeding disorders	82	15.27	163	30.35	**< 0.001**
Blood transfusions	12	2.23	34	6.33	**0.001**
Systemic sepsis	54	10.06	89	16.57	**0.002**
Functional status					**0.013**
Independent	298	55.49	353	65.74	
Partially dependent	112	20.86	148	27.56	
Totally dependent	22	4.10	29	5.40	
Laboratory values[a]					
Sodium (mEq/L)	137.894 ± 4.028		137.923 ± 4.147		0.875
Blood urea nitrogen (mg/dL)	22.584 ± 12.248		30.367 ± 17.299		**< 0.001**
Creatinine (mg/dL)	1.135 ± 1.056		1.402 ± 0.894		**0.015**
Albumin (g/dL)	3.474 ± 0.519		3.324 ± 0.580		**0.014**
White blood cells (10^3 c/mL)	9.948 ± 3.815		9.970 ± 4.238		0.279
Hematocrit (%)	36.365 ± 4.663		34.578 ± 5.061		0.062
Platelets (per mL)	203.906 ± 71.334		197.280 ± 84.567		**0.015**

Bolded values indicate statistical significance

[a]Congestive heart failure

[b]Standard deviation

[c]Chronic obstructive pulmonary disease

dyspnea ($p < 0.001$), ventilator dependence ($p = 0.015$), COPD ($p < 0.001$), dialysis dependence ($p = 0.018$), wound infections ($p = 0.007$), steroid use ($p = 0.001$), hematologic disorders ($p < 0.001$), blood transfusions ($p = 0.001$), sepsis ($p = 0.002$), and functional dependence ($p = 0.013$). Significant differences were also noted in laboratory values, such as blood urea nitrogen ($p < 0.001$), serum creatinine ($p = 0.015$), albumin ($p = 0.014$), and platelet count ($p = 0.015$; Table 1).

Operation-related variables that described surgical characteristics were also assessed for their differences between the two cohorts. Patients with a history of CHF had a significantly longer surgical delay (2.89 days vs. 1.48 days; $p < 0.001$) from admission, longer total hospital stay (10.50 days vs. 7.92 days; $p < 0.001$), longer time until discharge (7.64 days vs. 6.43 days; $p = 0.028$). Significantly higher rates of CHF patients were also discharged to destinations other than their own homes when compared to non-CHF patients ($p = 0.008$; Table 2).

The univariate analyses assessing differences in perioperative/postoperative variables and complications yielded significant findings for a multitude of acute adverse events occurring within 30 days following HHA. Patients with a history of CHF demonstrated significantly higher rates of postoperative pneumonia ($p < 0.001$), ventilator dependence for longer than 48 h ($p = 0.038$), progressive renal insufficiency ($p = 0.002$), cardiac arrest requiring CPR ($p = 0.017$), myocardial infarctions ($p = 0.020$), blood transfusions ($p = 0.025$), extended LOS (≥ 5 days, $p < 0.001$), unplanned readmission ($p = 0.033$), and mortality ($p < 0.001$; Table 3).

Upon further analysis of CHFs impact on these postoperative complications through multivariate regression analyses, risk for a total of seven complications was shown to be independently increased by CHF alone. CHF was a significant independent risk factor for postoperative pneumonia (OR 2.315, 95% CI 1.326–4.041, $p = 0.003$), progressive renal insufficiency (OR 8.915, 95% CI 1.103–72.074,

Table 2 Perioperative variables

	Control	%	CHF[a]	%	*p* value
	537		537		
Days to operation from admission	1.48 ± 2.501		2.89 ± 4.611		**< 0.001**
Total operating time (min)	76.45 ± 39.160		77.66 ± 38.532		0.355
Total hospital stay length (days)	7.92 ± 7.992		10.50 ± 10.113		**< 0.001**
Days from operation to death	15.53 ± 9.993		10.91 ± 8.905		0.153
Days from operation to discharge	6.43 ± 7.061		7.64 ± 7.874		**0.028**
Discharge destination					**0.008**
Home	84	15.64	90	16.76	
Other than home	314	58.47	350	65.18	
Not reported	139	25.88	97	18.06	
Care type					1.000
Inpatient	536	99.81	535	99.63	
Outpatient	1	0.19	2	0.37	
Anesthesia administered					0.413
Epidural	1	0.19	0	0.00	
General	373	69.46	364	67.78	
Local/regional	7	1.30	3	0.56	
MAC[b]/IV[c] sedation	21	3.91	18	3.35	
Spinal	135	25.14	152	28.31	
ASA classification					**< 0.001**
1—No disturb	1	0.19	0	0.00	
2—Mild disturb	96	17.88	12	2.23	
3—Severe disturb	334	62.20	239	44.51	
4—Life threat	105	19.55	280	52.14	
5—Moribund	1	0.19	4	0.74	
None assigned	0	0.00	2	0.37	

Bolded values indicate statistical significance

[a]Congestive heart failure

[b]Monitored anesthesia care

[c]Intravenous

[d]American Society of Anesthesiologists

Table 3 Univariate analyses for postoperative complications comparing CHF[a] and control cohorts

Postoperative complications	Control		CHF[a]		*p* value
	N	%	*N*	%	
	537		537		
Superficial incisional SSI[b]	2	0.37	4	0.74	0.687
Deep incisional SSI	536	99.81	533	99.26	0.374
Organ/space SSI	3	0.56	2	0.37	1.000
Wound disruption	0	0.00	2	0.37	0.500
Pneumonia	21	3.91	54	10.06	**< 0.001**
Unplanned intubation	6	1.12	12	2.23	0.154
Pulmonary embolism	4	0.74	8	1.49	0.246
Ventilator dependence (> 48 h)	1	0.19	8	1.49	**0.038**
Progressive renal insufficiency	1	0.19	12	2.23	**0.002**
Acute renal failure	533	99.26	530	98.70	0.363
Urinary tract infection	34	6.33	34	6.33	1.000
CVA[c]/stroke	4	0.74	5	0.93	1.000
Cardiac arrest	4	0.74	14	2.61	**0.017**
Myocardial infarction	6	1.12	17	3.17	**0.020**
Blood transfusions	110	20.48	141	26.26	**0.025**
Deep venous thromboembolism (DVT)	6	1.12	6	1.12	1.000
Systemic sepsis	9	1.68	14	2.61	0.292
Septic shock	4	0.74	10	1.86	0.107
Death	34	6.33	76	14.15	**< 0.001**
Return to operating room (OR)	17	3.17	24	4.47	0.265
Extended length of stay (≥ 5 days)	223	41.53	296	55.12	**< 0.001**
Readmission	49	9.12	71	13.22	**0.033**

Bolded values indicate statistical significance

[a]Congestive heart failure

[b]Surgical site infection

[c]Cerebrovascular accident

$p = 0.040$), MI (OR 2.737, 95% CI 0.999–7.502, $p = 0.050$), extended LOS for ≥ 5 days (OR 1.547, 95% CI 1.188–2.014, $p = 0.001$), and mortality (OR 2.234, 95% CI 1.406–3.549, $p = 0.001$; Table 4). Although significantly higher in prevalence between the two cohorts, the risk for postoperative ventilator dependence (> 48 h), MI, blood transfusions, and unplanned readmission within 30 days were not independently increased by CHF (Table 4).

Discussion

The results above demonstrate that CHF is a critical risk factor that influences perioperative and postoperative morbidity following HHA. In our evaluation of total hospital LOS after primary HHA, we found that CHF is a significant perioperative risk factor for increasing the total hospital LOS in primary HHA. Concurrently, this study found that CHF significantly increased days to operation from admission and days from operation to discharge, both of which explain the overall increased LOS. In addition to spending more time in the hospital itself, patients with CHF were found to be discharged to a non-home location more frequently than those without CHF. Increased LOS in orthopedic procedures is associated with increased postoperative morbidity, such as deep venous thromboembolisms [14], as well as increased cost burden to the healthcare system [15].

Several prior studies have identified that CHF is associated with increased LOS for surgical procedures [16, 17]. In 2017, Joseph et al. [18] found that congestive heart failure is the greatest predictor (of the nine variables found to independently associated) of increased LOS in a cohort of 92,266 patients from the NSQIP database undergoing any of 14 common orthopedic procedures. The selected procedures in this study did not include HHA but were inclusive of total hip arthroplasty. More specifically, Curtis et al. [11] and Higuera et al. [19] found CHF to be associated with a significant increase in LOS after total hip arthroplasty. However, to our knowledge there is a lack of literature discussing the impact of preoperative history of CHF on LOS among patients undergoing HHA in particular.

Table 4 Multivariate analyses assessing congestive heart failure as an independent risk factor for postoperative complications

Postoperative complications	Odds ratio	95% CI		*p* value
Superficial incisional SSI[a]	2.065	0.346	12.340	0.426
Deep incisional SSI	4.196	0.404	43.569	0.230
Organ/space SSI	0.619	0.086	4.433	0.633
Wound disruption	> 999.99	0.000	–	0.990
Pneumonia	2.315	1.326	4.041	**0.003**
Unplanned intubation	1.272	0.426	3.803	0.666
Pulmonary embolism	2.084	0.573	7.584	0.265
Ventilator dependence (> 48 h)	5.504	0.588	51.534	0.135
Progressive renal insufficiency	8.915	1.103	72.074	**0.040**
Acute renal failure	1.260	0.330	4.818	0.735
Urinary tract infection	1.140	0.666	1.951	0.632
CVA[b]/stroke	1.178	0.293	4.740	0.817
Cardiac arrest	2.510	0.777	8.107	0.124
Myocardial infarction	2.737	0.999	7.502	**0.050**
Blood transfusions	1.282	0.939	1.751	0.118
Deep venous thromboembolism (DVT)	1.149	0.298	4.426	0.841
Systemic sepsis	1.167	0.451	3.017	0.750
Septic shock	1.983	0.573	6.868	0.280
Death	2.234	1.406	3.549	**0.001**
Return to operating room	1.664	0.829	3.343	0.152
Extended length of stay (≥ 5 days)	1.547	1.188	2.014	**0.001**
Readmission	1.472	0.970	2.233	0.069

Bolded values indicate statistical significance

[a]Surgical site infection

[b]Cerebrovascular accident

Beyond LOS, this study found that CHF is an independent risk factor for developing pneumonia following HHA. Pneumonia following orthopedic surgery is not well understood, but it is a serious complication that has the potential to lead to hospital readmission. In a similar study seeking to identify independent preoperative risk factors for developing pneumonia following surgery for the geriatric hip fracture, Bohl et al. [20] found that 1 in 25 geriatric patients developed pneumonia following hip fracture surgery. In their study, CHF was found to be a statistically significant independent risk factor for pneumonia in this geriatric population in an inclusive cohort of hip procedures, including HHA, total hip arthroplasty, and open reduction and internal fixation (ORIF). Interestingly however, CHF did not demonstrate an increased risk for pneumonia in THA [11]. Although the mechanism as to how CHF precipitates pneumonia in HHA compared to THA is unclear, the current literature suggests that CHF patients undergoing HHA may be more vulnerable to pneumonia development [20]. The data from our study support this preexisting literature and emphasize the need for close monitoring of patient's respiratory status following HHA in particular. A lower threshold of suspicion for pneumonia development in the postoperative period should be maintained for these patients. More aggressive antibiotic prophylaxis may be considered for CHF patients in HHA compared to THA. However, future randomized control trials are required to determine the efficacy of higher potency antibiotic prophylaxis in reducing pneumonia complications in CHF patients undergoing HHA for FNF.

Pneumonia can also greatly increase the rates of bacterial sepsis [21]. Although our study identified systemic sepsis and septic shock as a significant complication associated with HHA in the setting of CHF, the significance was lost in regression of covariates, and was therefore not identified as a significant independent risk factor.

Additionally, this study found CHF to be an independent risk factor for MI in this study. The results of this study are in line with the current literature as CHF has been previously demonstrated to predispose patients to MI and other various cardiac complications in total joint arthroplasty procedures [22]. It is well known that previous MIs are a significant risk factor for subsequent CHF development in patients with cardiac disease. However, the inverse relationship has not been well reported and the underlying mechanism of CHF predisposing patients to having MI is, although likely multifactorial, not well understood. Of note, although MIs were significantly associated with CHF with $p = 0.05$, the 95% confidence interval was 0.999

through 2.737. Readers should interpret these findings within context and should keep in mind that the complication of MI may be different in a larger overall sample population of CHF patients undergoing HHA for FNF.

The current study also found an increased risk of progressive renal insufficiency due to CHF prior to HHA. CHF and kidney disease are tightly associated, and CHF is found in up to 70% of patients with end-stage renal disease [23]. Conversely, CHF is associated with clinically significant decline in renal function [24, 25]. Furthermore, there is evidence to suggest that arthroplasty is associated with decreased kidney function. Kimmel et al. [26] found a 15% incidence of acute kidney injury in a total joint arthroplasty population of 425 patients in which 173 were hip replacements. Ferguson et al. [27] found an increasing rate of acute kidney injury following total knee arthroplasty between 2004 to 2013. On the other hand, Kateros et al. [28] found that heart failure was not a significant preoperative risk factor for kidney disease in the orthopedic setting. However, the study included all emergency and elective orthopedic procedures and was not focused on hip arthroplasty. Additionally, this finding raises the concern for the need for careful review of the use of perioperative and postoperative medication usage in HHA patients with history of CHF. For example, pharmacological management of pain and antibiotic prophylaxis should be carefully selected due to the possibility of diminished renal metabolic function in these patients. Overall, the finding in this study helps to further the discussion over the need for renal function monitoring in patients with CHF, especially following HHA [24].

Like in THA, heart failure was also unsurprisingly found to be a significant risk factor for postsurgical mortality in HHA [11]. Rhee et al. [29] also identified heart failure among several other preoperative risk factors as increasing the risk of death following HHA. In 2013, one in nine individuals had heart failure mentioned on their death certificate [7]. The prevalence of heart failure is therefore quite appreciable, and its detrimental impacts on mortality are found postsurgically for HHA as well. CHF was also found to decrease the days to death in cases of surgery-related death for HHA. There is substantial evidence already in the literature that demonstrates an increased risk of perioperative complications including surgery-associated death in noncardiac surgery for patients with CHF [30]. Healy et al. [31] was able to associate the impact of left ventricular ejection fraction on perioperative outcomes in noncardiac surgery. They found that severely decreased ejection fraction (<30%) was associated with significantly increased adverse perioperative outcomes, including perioperative mortality. This raises the possibility of recommending cardiac function testing modalities as a standard of care to properly assess the risk for experiencing complications before orthopedic procedures such as HHA. Further research into its efficacy of predicting such postoperative complications is warranted.

This retrospective study presents with several limitations. Given that this study only included variables that had at least an 85% reporting rate in the NSQIP database, variables that could be indicative of more detailed underlying disease states may have been left out. Another potential limitation of this study is the lack of specific etiologies for the patients' history of CHF. CHF is a cardiovascular pathology that can be caused by multiple mechanisms. Given that each etiology represents a specific mechanism of disease, there could potentially be confounding variables that were not accounted for when patients were stratified into CHF and non-CHF cohorts. Though significant demographic features and preoperative comorbidities were controlled for in multivariate analyses, CHF patients still present with a number of associated diseases that have not all been detailed through the ACS-NSQIP database, such as pulmonary edema, sleep apnea, and anemia. The unlisted comorbidities could also represent systemic confounding variables that may have had some influence in our analyses assessing CHF as an independent risk factor for the complications studied, presenting as another limitation of the study.

Conclusion

This study has established CHF as an independent risk factor for numerous complications following HHA for FNF, including postoperative pneumonia, progressive renal insufficiency, MI, extended LOS for ≥ 5 days, and mortality. These results highlight the need for further studies to evaluate the timing of medical optimization of CHF before undergoing HHA. Furthermore, although HHA and THA are similar procedures, these results highlight the differences in complications seen in CHF patients undergoing these two operations with regards to. More specific precautionary measures must be taken to preemptively address potential complications in order to optimize favorable outcomes. In doing so, orthopedic surgeons can both reduce the societal burden associated with prolonged hospital stays while also improving the quality of patients' lives through HHA.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Coronel R, de Groot JR, van Lieshout JJ (2001) Defining heart failure. Cardiovasc Res 50:419–422

2. Tan LB, Williams SG, Tan DK, Cohen-Solal A (2010) So many definitions of heart failure: are they all universally valid? A critical appraisal. Expert Rev Cardiovasc Ther 8:217–228
3. Inamdar AA, Inamdar AC (2016) Heart failure: diagnosis, management and utilization. J Clin Med 5:62
4. Yancy CW, Jessup M, Bozkurt B et al (2013) 2013 ACCF/AHA guideline for the management of heart failure: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol 62:e147–e239
5. Pazos-Lopez P, Peteiro-Vazquez J, Carcia-Campos A, Garcia-Bueno L, de Torres JPA, Castro-Beiras A (2011) The causes, consequences, and treatment of left or right heart failure. Vasc Health Risk Manag 7:237–254
6. Savarese G, Lund LH (2017) Global public health burden of heart failure. Card Fail Rev 3:7–11
7. Writing Group Members, Mozaffarian D, Benjamin EJ et al (2016) American Heart Association Statistics Committee; Stroke Statistics Subcommittee. Heart disease and stroke statistics-2016 update: a report from the American Heart Association. Circulation 133:e38–e360
8. Salem KM, Shannak OA, Scammell BE, Moran CG (2014) Predictors and outcomes of treatment in hip hemiarthroplasty dislocation. Ann R Coll Surg Engl 96:446–451
9. Currie C, Partridge M, Plant F, Roberts J, Wakeman R, Williams A (2011) The National Hip Fracture Database National Report 2011. NHFD, London. https://www.nhfd.co.uk/003/hipfracturer.nsf/NHFDNationalReport2011_Final.pdf. Accessed 5 May 2018
10. Curtis GL, Newman JM, George J et al (2018) Perioperative outcomes and complications in patients with heart failure following total knee arthroplasty. J Arthroplasty 33:36–40
11. Curtis G, George J, Newman JM et al (2017) Heart failure and total hip arthroplasty: what are the perioperative outcomes and complications? J Hip Surg 01:140–145
12. American College of Surgeons National Surgical Quality Improvement Program. User Guide for the 2016 ACS NSQIP Participant Use Data File (PUF). https://www.facs.org/~/media/files/quality%20programs/nsqip/nsqip_puf_userguide_2016.ashx. Accessed 5 May 2018
13. American College of Surgeons National Surgical Quality Improvement Program (2013) User Guide for the 2012 ACS NSQIP Participant Use Data File (PUF). https://www.facs.org/~/media/files/quality%20programs/nsqip/ug12.ash. Accessed 5 May 2018
14. Lewis TC, Cortes J, Altshuler D, Papadopoulos J (2018) Venous thromboembolism prophylaxis: a narrative review with a focus on the high-risk critically ill patient. J Intensive Care Med. https://doi.org/10.1177/0885066618796486
15. Missios S, Bekelis K (2015) Hospitalization cost after spine surgery in the United States of America. J Clin Neurosci 22:1632–1637
16. Hernandez AF, Whellan DJ, Stroud S, Sun JL, O'Connor CM, Jollis JG (2004) Outcomes in heart failure patients after major noncardiac surgery. J Am Coll Cardiol 44:1446–1453
17. Menendez ME, Baker DK, Fryberger CT, Ponce BA (2015) Predictors of extended length of stay after elective shoulder arthroplasty. J Shoulder Elbow Surg 24:1527–1533
18. Joseph GJ, Noiseux NO, Otero JE, Gao Y, Shah AS (2017) Patient factors systematically influence hospital length of stay in common orthopaedic procedures. Iowa Orthop J 37:233–237
19. Higuera CA, Elsharkawy K, Klika AK, Brocone M, Barsoum WK (2011) 2010 mid-america orthopaedic association physician in training award: Predictors of early adverse outcomes after knee and hip arthroplasty in geriatric patients. Clin Orthop Relat Res 469:1391–1400
20. Bohl DD, Sershon RA, Saltzman BM, Darrith B, Della Valle CJ (2018) Incidence, risk factors, and clinical implications of pneumonia after surgery for geriatric hip fracture. J Arthroplasty 33:1552–1556
21. Martin GS, Mannino DM, Eaton S, Moss M (2003) The epidemiology of sepsis in the united states from 1979 through 2000. N Engl J Med 348:1546–1554
22. Basilico FC, Sweeney G, Losina E et al (2008) Risk factors for cardiovascular complications following total joint replacement surgery. Arthritis Rheum 58:1915–1920
23. Silverberg D, Wexler D, Blum M, Schwartz D, Iaina A (2004) The association between congestive heart failure and chronic renal disease. Curr Opin Nephrol Hypertens 13:163–170
24. Waldum B, Westheim AS, Sandvik L et al (2010) Renal function in outpatients with chronic heart failure. J Card Fail 16:374–380
25. Al-Naher A, Wright D, Devonald MAJ, Pirmohamed M (2018) Renal function monitoring in heart failure—what is the optimal frequency? A narrative review. Br J Clin Pharmacol 84:5–17
26. Kimmel LA, Wilson S, Janardan JD, Liew SM, Walker RG (2014) Incidence of acute kidney injury following total joint arthroplasty: a retrospective review by RIFLE criteria. Clin Kidney J 7:546–551
27. Ferguson KB, Winter A, Russo L et al (2017) Acute kidney injury following primary hip and knee arthroplasty surgery. Ann R Coll Surg Engl 99:307–312
28. Kateros K, Doulgerakis C, Galanakos SP, Sakellariou VI, Papadakis SA, Macheras GA (2013) Analysis of kidney dysfunction in orthopaedic patients. BMC Nephrol 13:101
29. Rhee C, Lethbridge L, Richardson G, Dunbar M (2018) Risk factors for infection, revision, death, blood transfusion and longer hospital stay 3 months and 1 year after primary total hip or knee arthroplasty. Can J Surg 61:165–176
30. Upshaw K, Kiernan MS (2013) Preoperative cardiac risk assessment for noncardiac surgery in patients with heart failure. Curr Heart Fail Rep 10:147–156
31. Healy KO, Waksmonski CA, Altman RK, Stetson PD, Reyentovich A, Maurer MS (2010) Perioperative outcome and long-term mortality for heart failure patients undergoing intermediate- and high-risk noncardiac surgery: impact of left ventricular ejection fraction. Congesi Heart Fail 16:45–49