Heliyon 9 (2023) e13117

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Risk factors of serious postoperative outcomes in patients aged ≥90 years undergoing surgical intervention

Hong Fu [a,1,*], Jiang Zheng [a,1], Jingyi Lai [a,1], Victor W. Xia [b,c], Kaiping He [d], Dingyuan Du [e,**]

[a] *Department of Anesthesiology, Chongqing Emergency Medical Center, Chongqing University Central Hospital, School of Medicine, Chongqing University, Chongqing, China*
[b] *Department of Anesthesiology and Perioperative Medicine, Ronald Reagan UCLA Medical Center, Los Angeles, USA*
[c] *David Geffen School of Medicine at UCLA, Los Angeles, USA*
[d] *Division of Medical Record Statistical, Chongqing Emergency Medical Center, Chongqing University Central Hospital, School of Medicine, Chongqing University, Chongqing, China*
[e] *Department of Traumatology, Chongqing Emergency Medical Center, Chongqing University Central Hospital, School of Medicine, Chongqing University, Chongqing, China*

ARTICLE INFO

Keywords:
Aged ≥90 years
Surgery
Risk factor
Serious postoperative outcome

ABSTRACT

Objective: We aimed to identify preoperative and intraoperative factors associated with serious postoperative outcomes, which may help patients and clinicians make better-informed decisions.
Methods: We conducted a retrospective study including all patients aged ≥90 years who underwent surgery between January 1, 2011, and January 1, 2021, at Chongqing University Central Hospital. We assessed 30 pre- and intraoperative demographic and clinical variables. Logistic regression was used to identify the independent risk factors for serious postoperative outcomes in patients aged ≥90 years.
Results: A total of 428 patients were included in our analysis. The mean age was 92.6 years (SD ± 2.6). There were 240 (56.1%) females and 188 (43.9%) males. The most common comorbidities were hypertension (44.9%) and arrhythmias (34.8%). The 30-day hospital mortality was 5.6%, and severe morbidity was 33.2%. Based on the multivariate logistic regression classification analysis of the American Society of Anesthesiologists (ASA)≥ Ⅳ [odds ratio (OR), 5.39, 95% confidence interval (CI), 2.06–14.16, P = .001], emergency surgery (OR, 5.02, 95% CI, 2.85–15.98, P = .001) and chronic heart failure (OR, 6.11, 95% CI, 1.93–13.06, P = .001) were identified as independent risk factors for 30-day hospital mortality, and ASA≥ Ⅳ (OR, 4.56, 95% CI, 2.56–8.15, P < .001), Barthel index (BI) < 35 (OR, 2.28, 95%CI, 1.30–3.98, P = .001), chronic heart failure (OR, 3.67, 95%CI, 1.62–8.31, P = .002), chronic kidney disease (OR, 4.24, 95%CI, 1.99–9.05, P < .001), general anesthesia (OR, 3.31, 95%CI, 1.91–5.76, P < .001), emergency surgery (OR, 3.72, 95%CI, 1.98–6.99, P < .001), and major surgery (OR, 3.44, 95%CI, 1.90–6.22, P < .001) were identified as independent risk factors for serious postoperative complications.

* Corresponding author. Department of Anesthesiology, Chongqing Emergency Medical Center, Chongqing University Central Hospital, School of Medicine, Chongqing University, No 1, JianKang Road, Yuzhong District, Chongqing 400014, China.
** Corresponding author. Department of traumatology, Chongqing Emergency Medical Center, Chongqing University Central Hospital, School of Medicine, Chongqing University, Chongqing 400014, China.
E-mail addresses: fuhong1974@cqu.edu.cn (H. Fu), dudingyuan@qq.com (D. Du).
[1] These authors contributed equally to this work.

https://doi.org/10.1016/j.heliyon.2023.e13117
Received 10 October 2022; Received in revised form 17 January 2023; Accepted 18 January 2023
Available online 21 January 2023

Conclusions: Patients aged ≥90 years with ASA≥ Ⅳ, BI < 35, combined with chronic heart failure or chronic kidney disease, undergoing emergency surgery, major surgery or general anesthesia have a higher risk of serious postoperative outcomes. Identifying these risk factors in an early stage may contribute to our clinical decision-making and improve the quality of treatments.

1. Introduction

In 2020, there were an estimated 1.5 billion people aged ≥60 years worldwide, comprising 13.5% of the global population. The number of people aged ≥90 around the world is estimated to be nearly fourfold by 2050 (from 21 million in 2020 to 77 million) and will increase nearly eleven-fold by 2100 [1]. Because of life extension and advances in surgical and anesthetic techniques in recent decades, the number of older patients undergoing surgery has increased, and the population of patients aged ≥90 who need surgical intervention has also increased [2].

However, the change in physiological and related decreases in function and increased comorbid burdens have a great effect on postoperative complications in older adults, and surgical intervention seems to be a challenge for them [3,4]. Some studies have found that a history of congestive heart failure, neurological diseases, American Society of Anesthesiologists (ASA) classification, perioperative blood transfusion and emergency surgery are risk factors for postoperative adverse events among patients aged ≥80 [5–7]. However, these studies included some common but limited harmful complications, such as urinary tract infections and superficial wound infections, which may exaggerate the postoperative adverse events and alter the clinical decision. The Pareto principle applies to the elaborate process of postoperative death after complications. Specifically, 20% of patients with the highest risk of postoperative complications are responsible for approximately 90% of failure-to-rescue [8]. Few studies have focused on the risk factors for serious outcomes individually among people aged ≥90.

The aim of this study was to explore the risk factors for serious postoperative outcomes in patients aged ≥90 years undergoing surgical intervention in order to help identify and focus on these factors in early stages and support clinical decision-making.

2. Methods

A retrospective study was conducted on patients 90 years old or older who underwent surgery at Chongqing University Central Hospital between January 1, 2011, and January 1, 2021. The hospital is a tertiary hospital with 1200 beds that integrates first aid, medical treatment, teaching, scientific research, prevention, and rehabilitation in Chongqing. We recruited all patients aged ≥90 years who underwent surgical procedures during the ten year period and excluded colonoscopies, bronchoscopies, thoracentesis, arteriovenous puncture, and other noninvasive monitoring. All information was collected by reviewing the hospital information system (HIS), electronic medical record system, laboratory examinations and image recordings, anesthesia, and nursing record sheets. Preoperative comorbidity was identified in the HIS according to the international classification of diseases (ICD-10). Postoperative complications were recorded in the medical recording. We retrospectively performed this study, and informed consent was exempted. The study conformed to the Declaration of Helsinki and was approved by the ethics committee of Chongqing University Central Hospital (NO. 2022 [49]).

2.1. Preoperative information

The demographic characteristics included age, sex, Barthel index (BI), and ASA score. Preoperative comorbidities included cardiovascular disease [coronary artery disease, hypertension, chronic heart failure (CHF), arrhythmia], pulmonary disease [pneumonia, chronic obstructive pulmonary disease (COPD), asthma, pulmonary embolism, bronchial disease including bronchitis and bronchiectasis], neurological disease (dementia, seizure disorder, cerebrovascular disease including cerebral hemorrhage and infarction), chronic kidney disease (CKD) and diabetes. Preoperative laboratory values included potassium, sodium, hemoglobin, albumin, platelet and white blood cell count.

2.2. Intraoperative events

The intraoperative variables included types of surgery and anesthesia, use of vasopressors, transfusions, surgical time and intraoperative bleeding. Surgery included elective and emergency surgery. In addition, we divided surgery into two parts according to the site, wound size, and complexity of operation. Major surgery was defined as an operation in a deep organ or a large wound or a complex procedure, e.g., colon cancer resection, hip replacement, transurethral resection of the prostate (TURP). In contrast, minor surgery was defined as a superficial operation or had a small wound size or was easy to perform, such as herniorrhaphy, appendectomy, and percutaneous vertebroplasty (PVP). The methods of anesthesia were divided into two parts: general and nongeneral. General anesthesia was defined as anesthesia with intubation or laryngeal mask requiring mechanical ventilation. Nongeneral anesthesia included regional, combined general and regional, and topical anesthesia. Transfusion was defined as transfusion of any blood product during the pre- and intraoperative periods. Vasopressors included dopamine, noradrenaline, and epinephrine.

2.3. Serious postoperative outcomes

Serious postoperative outcomes included death and serious complications, which were defined as serious outcomes that occurred before hospital discharge within 30 postoperative days. Postoperative serious complications included myocardial infarction and cardiac arrest, unplanned intubation, deep venous thrombosis (DVT), pulmonary embolism, mechanical ventilation ≥48 h, new stroke or coma, acute kidney injury (AKI) or dialysis, wound dehiscence, deep surgical wound infection and organ space surgical site infection, septic shock or bloodborne sepsis, postoperative bleeding or second operation. Victor A et al. described these serious complications in a previous study [8]. In addition, we included acute heart failure (AHF) and respiratory failure as serious complications due to the great harm to patients, and unplanned admission to the intensive care unit (ICU) as this meant the patients were in a critical condition. AHF was defined as a rapid onset of new or worsening signs and symptoms of heart failure. Other complications were recorded in the HIS and electronic and written case notes.

2.4. Statistical analysis

Continuous variables were described as the means ± standard deviations (SD), while counts and percentages were used for categorical variables. The chi-squared test or Fisher's exact test was used to compare proportions, and numerical variables were compared with the unpaired Student's *t*-test or Mann–Whitney *U* test. In addition, variables with a p value less than 0.05 in univariate analysis were included in a forward stepwise logistic regression analysis. The results were displayed as odds ratios with 95% confidence intervals (CIs). A P value $< .05$ was considered to show statistical significance. All statistical analyses were performed using SPSS v.24 software (IBM Corporation, Armonk, NY, USA). The figure was generated by GraphPad Prism v.7.00 for Windows (GraphPad Software, Inc., California, USA).

3. Results

A total of 897 patients were identified, and 467 patients having had nonsurgical treatments, including endoscopy, arteriovenous puncture and noninvasive monitoring or treatments, one missing record, and one intraoperative death, were excluded. A total of 428 patients were included in the analysis. Table 1 shows that the mean age was 92.6 years (SD ± 2.6), and the range was 90–104 years. There were 240 (56.1%) females and 188 (43.9%) males. The mean BI score was 36.6 (SD ± 24.1). The patients' ASA classifications

Table 1
Clinical characteristics of patients aged 90 or older.

Preoperative conditions	Overall N = 428, No. (%)
Age, Mean ± SD	92.6 ± 2.6
Sex	
Female	240 (56.1)
Male	188 (43.9)
BI	36.6 ± 24.1
ASA	
I	3 (0.7)
II	65 (15.2)
III	259 (60.4)
IV	98 (22.9)
V	3 (0.7)
Comorbidity	
Cardiovascular disease	303 (70.80)
Hypertension	192 (44.9)
CAD	138 (32.2)
CHF	38 (8.9)
Arrhythmia	149 (34.8)
Pulmonary disease	139 (32.5)
Pneumonia	86 (20.1)
COPD	53 (12.4)
Asthma	5 (1.2)
PE	1 (0.2)
Bronchial disease	25 (5.8)
Neurological disease	126 (29.4)
Dementia	26 (6.1)
Seizure disorder	5 (1.2)
Cerebrovascular disease	112 (26.2)
CKD	54 (12.6)
Diabetes	62 (14.5)

Abbreviations: SD, standard deviation; BI, Barthel index; ASA, American Society of Anesthesiologists; CAD, coronary artery disease; CHF, chronic heart failure; COPD, chronic obstructive pulmonary disease; PE, pulmonary embolism; CKD, chronic kidney disease.

were as follows: 3 patients (0.7%) were categorized as ASA I, 65 patients (15.2%) were ASA II, 259 patients (60.4%) were ASA III, 98 patients (22.9%) were ASA Ⅳ and 3 patients (0.7%) were ASA Ⅴ. Comorbidities were extremely common, and many patients had multiple medical diagnoses. The most common diseases were hypertension (44.9%), arrhythmias (34.8%), cerebral hemorrhage or infarctions (26.2%), pneumonia (20.1%), and diabetes (14.5%). There were 38 patients (8.9%) with CHF and 54 patients with CKD (12.6%).

The preoperative laboratory value and intraoperative conditions are shown in Table 2. Mean potassium was 4.0 mmol/L (SD ± 0.5), sodium was 138.8 (SD ± 7.4), hemoglobin was 10.8 g/dl (SD ± 2.1), albumin was 36.4 (SD ± 5.0), platelet count was 183 × 10^9/L (SD ± 80), and white blood cell count was 8.2 × 10^9/L (SD ± 3.9). The specific distribution of surgical procedures was as follows: orthopedics (n = 184, 42.5%), general surgery (n = 79, 18.5%), neurosurgery (n = 38, 8.9%), spine (n = 39, 9.1%), urology (n = 20, 5.5%), ophthalmology (n = 43, 10.0%), and superficial surgery (n = 20, 4.7%). Arthroplasties of the hip, repair of hip fractures, and exploratory laparotomies were the most common surgeries. Ninety-five patients (22.2%) underwent emergency surgery, and 123 patients (28.7%) underwent general anesthesia. A total of 224 patients (52.3%) underwent major surgery, and 204 (47.7%) patients underwent minor surgery. The mean surgical time was 84.1 min and mean bleeding was 139.5 mL. A total of 182 patients (42.5%) used vasopressors, and 154 patients (36.0%) were transfused during the pre- and intraoperative periods.

Table 3 illustrates the distribution of serious postoperative outcomes. The overall serious postoperative outcome rate following surgery in this series of 428 patients was 33.9%, 24 patients (5.6%) died within 30 days after surgery, 21 patients died combined with serious complications, 142 patients (33.2%) suffered serious complications, 94 patients (22.0%) had an unplanned admission to the ICU, 70 patients (16.4%) had pulmonary complications, 31 patients (7.2%) had renal complications and 26 patients (6.1%) had cardiac complications.

The univariate analysis of serious postoperative outcomes is shown in Table 4. The pre- and intraoperative risk factors for serious postoperative outcomes included a history of CAD, CHF, pneumonia, COPD, seizure disorder, CKD, the level of BI, ASA, WBC, albumin and hemoglobin, or the use of vasopressors and blood products during the period, general anesthesia, emergency surgery, major surgery, surgical time and intraoperative bleeding. These variables were included in the multivariate analysis.

Fig. 1 displays the results of the multivariate analysis for serious postoperative outcomes. ASA≥ Ⅳ (OR, 5.39, 95% CI, 2.06–14.16, P = .001), emergency surgery (OR, 5.02, 95% CI, 2.85–15.98, P = .001), and CHF (OR, 6.11, 95% CI, 1.93–13.06, P = .001) were identified as independent risk factors for 30-day hospital mortality.

The variables ASA classification, BI score, CHF, CKD, general anesthesia, emergency surgery and major surgery were statistically significant in the multivariate analysis. ASA≥ Ⅳ (OR, 4.56, 95% CI, 2.56–8.15, P < .001), BI < 35 (OR, 2.28, 95% CI, 1.30–3.98, P = .001), CHF (OR, 3.67, 95% CI, 1.62–8.31, P = .002), CKD (OR, 4.24, 95% CI, 1.99–9.05, P < .001), general anesthesia (OR, 3.31, 95% CI, 1.91–5.76, P < .001), emergency surgery (OR, 3.72, 95% CI, 1.98–6.99, P < .001), and major surgery (OR, 3.44, 95% CI, 1.90–6.22, P < .001).

Table 2
Preoperative laboratory value and intraoperative condition.

Preoperative Laboratory Value, Mean ± SD	Overall N = 428
Potassium (mmol/L)	4.0 ± 0.5
Sodium (mmol/L)	138.8 ± 7.4
Platelet (10^9/L)	183 ± 80
WBC (10^9/L)	8.2 ± 3.9
Albumin (g/L)	36.4 ± 5.0
Hemoglobin (g/dl)	10.8 ± 2.1
Pre- and intra-operative events, No. (%)	
Vasopressor	182 (42.5)
Transfusion	154 (36.0)
Types of surgery	
Emergency	95 (22.2)
Elective	333 (77.8)
Types of anesthesia	
General	123 (28.7)
Non-general	305 (71.3)
Types of surgery	
Orthopedics	182 (42.5)
General surgery	79 (18.5)
Neurosurgery	38 (8.9)
Spine surgery	39 (9.1)
Urology	27 (6.3)
Ophthalmology	43 (10.0)
Superficial surgery	20 (4.7)
Classification of surgery	
Major	224 (52.3)
Minor	204 (47.7)
Surgical time (min), Mean ± SD	84.1 ± 52.6
Intraoperative bleeding (mL), Mean ± SD	139.5 ± 186.5

Abbreviations: SD, standard deviation; WBC, white blood cell.

Table 3
Distribution of serious postoperative outcomes.

Types of serious outcomes (Overlap)	Number of patients (%)
Death	24 (5.6)
Died with serious complications	21
Without serious complications	3
Cardiac complications	26 (6.1)
AHF	22
Cardiac arrest	2
Myocardial infarction	2
Pulmonary complications	70 (16.4)
Pneumonia	40
Unplanned intubation	3
DVT, PE	6
Respiratory failure	6
Mechanical ventilation≥48 h	2
≥2 pulmonary complications	13
CNS complications	2 (0.5)
Stroke	2
Renal complications	31 (7.2)
AKI	30
Dialysis	1
Septic shock, bloodborne sepsis	12 (2.8)
Deep surgical wound infection	1 (0.2)
Unplanned admission to ICU	94 (22.0)

Abbreviations: AHF, acute heart failure; DVT, deep venous thrombosis; PE, pulmonary embolism; CNS, central nervous system; AKI, acute kidney injury; ICU, intensive care unit.

Table 4
Univariate Analysis of Preoperative and Intraoperative Risk Factors of Postoperative outcomes.

Risk factors	30-day Hospital Death N = 24			Severe Complications N = 142		
	No. (%)	OR (95%CI)	P value	No. (%)	OR (95%CI)	P value
Female	11 (45.8)	0.65 (0.28–1.48)	.30	78 (54.9)	0.93 (0.62–1.40)	.74
ASA≥ Ⅳ	17 (70.8)	9.11 (3.66–22.69)	<.001	68 (47.9)	6.81 (4.19–11.08)	<.001
Hypertension	9 (37.5)	0.73 (0.31–1.69)	.46	66 (46.5)	1.10 (0.74–1.65)	.64
CAD	9 (37.5)	1.28 (0.55–3.00)	.57	59 (41.5)	1.86 (1.22–2.84)	.004
CHF	8 (33.3)	6.75 (2.85–15.98)	<.001	24 (16.9)	3.95 (1.98–7.91)	<.001
Arrhythmia	10 (41.7)	1.36 (0.59–3.15)	.47	51 (35.9)	1.08 (0.71–1.64)	.74
Pneumonia	6 (25.0)	1.35 (0.52–3.51)	.72	45 (31.7)	2.77 (1.71–4.50)	<.001
COPD	3 (12.5)	1.01 (0.29–3.51)	1.00	27 (19.0)	2.35 (1.31–4.20)	.003
Asthma	1 (4.2)	4.35 (0.47–40.49)	.25	3 (2.1)	3.07 (0.51–18.55)	.34
PE	0	1.00 (0.99–1.00)	1.00	0	1.00 (0.99–1.00)	1.00
Bronchial disease	0	0.94 (0.92–0.96)	.42	9 (6.3)	1.14 (0.49–2.65)	.76
Dementia	1 (4.1)	0.66 (0.09–5.08)	1.00	8 (5.6)	0.89 (0.38–2.10)	.79
Seizure disorder	0	0.99 (0.98–1.00)	1.00	4 (2.8)	8.26 (0.92–74.61)	.046
Cerebrovascular disease	8 (33.3)	1.44 (0.60–3.47)	.41	43 (30.3)	1.37 (0.87–2.14)	.17
CKD	6 (25.0)	2.47 (0.94–6.53)	.12	32 (22.5)	3.49 (1.94–6.28)	<.001
Diabetes	6 (25.0)	2.07 (0.79–5.44)	.23	19 (13.4)	0.87 (0.49–1.56)	.65
Transfusion	8 (33.3)	0.88 (0.37–2.12)	.78	67 (47.2)	2.04 (1.35–3.09)	.001
Emergency	15 (62.5)	6.75 (2.85–15.98)	<.001	59 (41.5)	4.94 (3.05–8.00)	<.001
General anesthesia	12 (50.0)	2.64 (1.15–6.05)	.018	74 (52.1)	5.26 (3.35–8.26)	<.001
Major Surgery	13 (54.2)	1.08 (0.47–2.47)	<.001	97 (68.3)	2.70 (1.77–4.12)	<.001
BI, Mean ± SD	17.7 ± 16.7		<.001	26.6 ± 19.3		<.001
Potassium (mmol/L)	4.2 ± 0.5		.16	4.1 ± 0.6		.30
Sodium (mmol/L)	137.7 ± 4.4		.55	138.4 ± 5.2		.76
Platelet (10^9/L)	179 ± 71		.81	193.3 ± 88.8		.11
WBC(10^9/L)	10.1 ± 4.7		.013	9.0 ± 3.9		<.001
Albumin (g/L)	34.3 ± 5.0		.035	34.9 ± 5.0		<.001
Hemoglobin (g/dl)	9.8 ± 2.3		.020	10.3 ± 2.3		<.001
Surgical time (min)	82.4 ± 46.8		.79	103.1 ± 60.3		<.001
Intraoperative bleeding (mL)	140.2 ± 210.9		.99	117.7 ± 170.6		<.001

Abbreviations: OR, odds ratio; CI, confidence interval; ASA, American Society of Anesthesiologists; CAD, coronary artery disease; CHF, chronic heart failure; COPD, chronic obstructive pulmonary disease; PE, pulmonary embolism; CKD, chronic kidney disease; BI, Barthel index; SD, standard deviation; WBC, white blood cell.

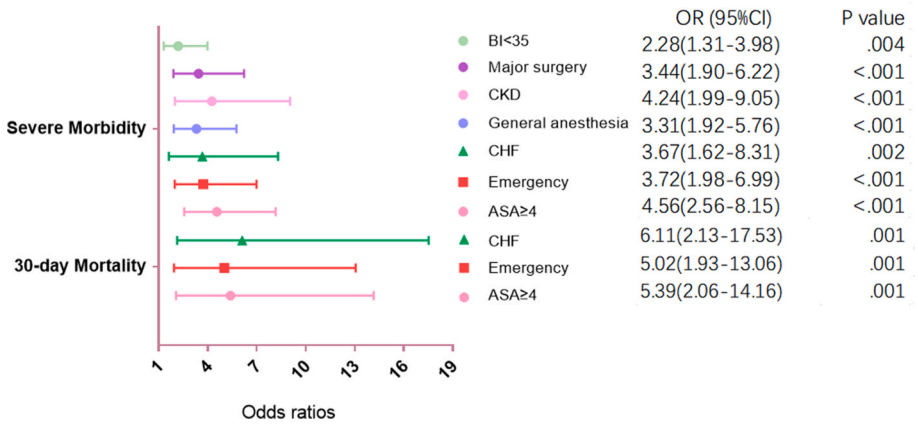

Fig. 1. Risks of Serious Postoperative Outcomes by Multivariate Analysis. Abbreviations: OR, odds ratio; CI, confidence interval; ASA, American Society of Anesthesiologists; CHF, chronic heart failure; CKD, chronic renal disease; BI, Barthel index.

4. Discussion

To our knowledge, few studies have focused on the risk factors for adverse outcomes among patients 90 years or older who undergo surgical intervention, especially serious postoperative outcomes after different surgeries. Previous studies were focused on specific types of surgeries, e.g., HIP replacement and abdominal or emergency surgery [9–11].

In our study, the overall 30-day mortality was 5.6%. This result was less than that of another study (6.2%) which focused on patients aged ≥90 years in a general surgical setting [12]. Different study designs may lead to inconsistent results. Our study included minor surgeries, such as PVP and phacoemulsification, while the previous study only included patients undergoing general surgery. It is obvious that their study population had a higher risk of death than ours. Regarding morbidity, although we only included serious complications and excluded minor complications such as UTI and postoperative transfusion, the morbidity was still high (33.2%). The most common serious complication was unplanned admission to the ICU (22.0%), which may be linked to unstable circulation, breathing with ventilators, loss of too much blood during the operation or serious illness requiring life support.

In our setting, ASA classification, emergency surgery and CHF were independent risk factors for mortality and morbidity. Several studies concluded that ASA classification provides a good indication of adverse postoperative outcomes in patients aged ≥90 years [2,13,14]. ASA III (60.4%) predominated in the present study and was similar (51.8%) to the previous study [15]. We tried to find a relationship between ASA III and serious postoperative outcomes. We found that ASA III was significantly associated with serious outcomes; however, few patients had serious postoperative outcomes (only one patient had unplanned admission to the ICU). For patients with ASA < III, the outcome of multivariate analysis seemed not to be reliable (the range of OR 95% CI was too wide), so we included ASA ≥ IV in the analysis. In the ASA classification a higher grade implies worse status, which can alter decision-making in the operating room [16]. ASA IV implies that extreme systemic disease has become a significant threat to life, and it is easy to understand that patients with ASA ≥ Ⅳ are in a dangerous situation. In addition, patients undergoing emergency surgery are in critical condition and there is not enough time to prepare them well for an operation. Evaluating the time of surgery, preparing patients as well as possible, and paying more attention to them in the whole perioperative period is necessary.

CHF was also associated with increased mortality, and morbidity was similar to previous studies [17,18]. CHF is a serious co-morbidity associated with high mortality and health care resource utilization [19]. Awareness of the impact of CHF on surgical outcomes is important to both doctors and patients, and anesthesiologists and surgeons should care about treatment during the perioperative period. Interestingly, we found that CKD was not associated with increased mortality but was associated with morbidity, a finding that partly different from another study, which found that CKD increased the risk of postoperative morbidity and mortality following major abdominal surgery [20]. A study similar to ours showed that CKD was related to increased morbidity after elective orthopedic surgery [21]. Furthermore, Miyake K et al. found that AKI only, AKI superimposed on CKD, and end-stage renal disease (ESRD) are independent risk factors for mortality, while CKD alone is not associated with mortality [22]. AKI and CKD are interconnected syndromes, and the presence of CKD is an important risk factor for the development of AKI [23]. Patients with CHF or CKD are in a pathological condition that cannot be healed but can made stable. It is necessary to postpone elective surgery in acute onset status. In addition, fluid therapy is common in patients with CKD or CHF; perhaps we should balance the fluid during the perioperative period; too much fluid may induce AHF in patients with underlying impaired cardiac function, and fluid overload is associated with AKI [24,25]. A restrictive fluid regimen is associated with a higher rate of AKI than a liberal one in major abdominal surgery [26]. Fluid management and goal-directed therapy may be necessary for patients in the perioperative period, especially for patients aged ≥90 years.

Other factors related to serious postoperative outcomes are general anesthesia and major surgery. Increased age and decreased physiological reserve hinder the body's ability to maintain homeostasis during times of physiological stress [27]. The use of anesthetics affects patients' circulation, breathing and other organ function. Decreased drug tolerance and metabolism prolong the relative risk period. In this condition, general anesthesia seems to be a risk for them, and they are more likely to have serious postoperative

outcomes. In our study, major surgery means a longer operation time, larger wound, and more complicated procedure than minor surgery. It is reasonable that patients undergoing major surgery are at greater risk of serious outcomes than those who undergo minor surgery.

BI is a tool to assess the activities of daily living (ADL), which consists of 10 items, including ordinal assessment (0–100 points) [28]. Patients with lower BI scores have a poor ability to perform ADL. In the present study, the mean BI score was 36.6, which implies that most patients are in a dependent situation and are unable to perform ADL by themselves. Several studies found that a dependent situation is related to higher mortality in adults aged ≥90 years undergoing abdominal aortic aneurysm repair and hemiarthroplasty [29,30]. In our study, patients with BI scores <35 were more likely to have serious outcomes. Thus, the BI score ought to be considered as part of the process of therapeutic decision-making.

Surgical intervention seems to be a challenge for patients aged ≥90 years because of insufficient function and decreased physiological and multiple comorbidities. However, the greatest challenges are social issues, including short life expectancy, quality of life and economy. Judging the risk/benefit ratio of surgery is often difficult, so our study may help clinical decision-making during the preoperative period.

Our study has some notable limitations. First, it was a retrospective study of different types of surgery in a single center, and the correlation does not necessarily imply causation. Second, our sample size was relatively small, and the distribution of data was inevitably scattered. More studies focusing on patients 90 years or older need to be performed in the future.

5. Conclusions

In summary, our study indicates that ASA≥ Ⅳ, BI score<35, emergency surgery, major surgery, general anesthesia, and combined CHF or CKD preoperatively are associated with serious postoperative outcomes among patients aged ≥90 years undergoing surgical intervention. We should pay more attention to these patients during the perioperative period, which may help to reduce the incidence of serious postoperative outcomes and improve the quality of treatments.

Author contribution statement

Hong Fu: Conceived and designed the experiments; Wrote the paper.

Jiang Zheng, Jingyi Lai: Contributed regents, materials, analysis tools or data; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Kaiping He: Contributed regents, materials, analysis tools or data.

Dingyuan Du, Victor W Xia: Conceived and designed the experiments; Wrote the paper.

Funding statement

Hong Fu was supported by Chongqing Municipal Health Commission [ZQNYXGDRCGZS2019006]. Dingyuan Du was supported by Chongqing Emergency Medical Center (jjzx2021-gjesqyylzx01) and Chongqing Municipality Science and Technology [cstc2022ycjh-bgzxm0245].

This work was supported by National Health Commission of the People's Republic of China [jjzx2021-gjesqyylzx01].

Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] World population prospects - population division - united nations, Available from: Accessed on, https://population.un.org/wpp/Download/Standard/Population/ (Accessed 17 May 2022).

[2] R. Fariña-Castro, C. Roque-Castellano, M. Artiles-Armas, J. Marchena-Gómez, Emergency surgery and American Society of Anesthesiologists physical status score are the most influential risk factors of death in nonagenarian surgical patients, Geriatr. Gerontol. Int. 19 (4) (2019) 293–298.

[3] B.D. Alvis, C.G. Hughes, Physiology considerations in geriatric patients, Anesthesiol. Clin. 33 (3) (2015) 447–456.

[4] H. Chikuda, H. Yasunaga, H. Horiguchi, K. Takeshita, S. Sugita, S. Taketomi, et al., Impact of age and comorbidity burden on mortality and major complications in older adults undergoing orthopaedic surgery: an analysis using the Japanese diagnosis procedure combination database, BMC Muscoskel. Disord. 14 (2013) 173.

[5] L.L. Liu, J.M. Leung, Predicting adverse postoperative outcomes in patients aged 80 years or older, J. Am. Geriatr. Soc. 48 (4) (2000) 405–412.

[6] J.Y. Chung, W.Y. Chang, T.W. Lin, J.R. Lu, M.W. Yang, C.C. Lin, et al., An analysis of surgical outcomes in patients aged 80 years and older, Acta Anaesthesiol. Taiwanica 52 (4) (2014) 153–158.

[7] C. Roque-Castellano, J. Marchena-Gómez, R. Fariña-Castro, M.A. Acosta-Mérida, M.D. Armas-Ojeda, M.I. Sánchez-Guédez, Perioperative blood transfusion is associated with an increased mortality in older surgical patients, World J. Surg. 40 (8) (2016) 1795–1801.

[8] V.A. Ferraris, M. Bolanos, J.T. Martin, A. Mahan, S.P. Saha, Identification of patients with postoperative complications who are at risk for failure to rescue, JAMA Surg 149 (11) (2014) 1103–1108.
[9] W.T. Lin, C.M. Chao, H.C. Liu, Y.J. Li, W.J. Lee, C.C. Lai, Short-term outcomes of hip fractures in patients aged 90 years old and over receiving surgical intervention, PLoS One 10 (5) (2015), e0125496.
[10] H. Perregaard, J. Tenma, J. Antonsen, T. Mynster, Mortality after abdominal emergency surgery in nonagenarians, Eur. J. Trauma Emerg. Surg. 47 (2) (2021) 485–492.
[11] A. Fansa, S. Huff, N. Ebraheim, Prediction of mortality in nonagenarians following the surgical repair of hip fractures, Clin. Orthop. Surg. 8 (2) (2016) 140–145.
[12] A. Sudlow, H. Tuffaha, A.T. Stearns, I.A. Shaikh, Outcomes of surgery in patients aged ≥90 years in the general surgical setting, Ann. R. Coll. Surg. Engl. 100 (3) (2018) 172–177.
[13] A.D. Pelavski, A. Lacasta, M.I. Rochera, M. de Miguel, J. Roigé, Observational study of nonogenarians undergoing emergency, non-trauma surgery, Br. J. Anaesth. 106 (2) (2011) 189–193.
[14] J. Racz, L. Dubois, A. Katchky, W. Wall, Elective and emergency abdominal surgery in patients 90 years of age or older, Can. J. Surg. 55 (5) (2012) 322–328.
[15] M. Kongwibulwut, K. Chiang, J.M. Lee, A.I. Eid, N. Kongkaewpaisan, K. Han, et al., Life after 90: predictors of mortality and performance of the ACS-NSQIP risk calculator in 4,724 nonagenarian patients undergoing emergency general surgery, J Trauma Acute Care Surg 86 (5) (2019) 853–857.
[16] M.M. Luedi, P. Kauf, L. Mulks, K. Wieferich, R. Schiffer, D. Doll, Implications of patient age and ASA physical status for operating room management decisions, Anesth. Analg. 122 (4) (2016) 1169–1177.
[17] F.E. Turrentine, M.W. Sohn, R.S. Jones, Congestive heart failure and noncardiac operations: risk of serious morbidity, readmission, reoperation, and mortality, J. Am. Coll. Surg. 222 (6) (2016) 1220–1229.
[18] N.R. Smilowitz, D. Banco, S.D. Katz, J.A. Beckman, J.S. Berger, Association between heart failure and perioperative outcomes in patients undergoing non-cardiac surgery, Eur Heart J Qual Care Clin Outcomes 7 (1) (2021) 68–75.
[19] J. Huusko, S. Kurki, I. Toppila, T. Purmonen, M. Lassenius, E. Gullberg, et al., Heart failure in Finland: clinical characteristics, mortality, and healthcare resource use, ESC Heart Fail 6 (4) (2019) 603–612.
[20] J.M. Cloyd, Y. Ma, J.M. Morton, M. Kurella Tamura, G.A. Poultsides, B.C. Visser, Does chronic kidney disease affect outcomes after major abdominal surgery? Results from the National Surgical Quality Improvement Program, J. Gastrointest. Surg. 18 (3) (2014) 605–612.
[21] G.L. Ackland, N. Moran, S. Cone, M.P. Grocott, M.G. Mythen, Chronic kidney disease and postoperative morbidity after elective orthopedic surgery, Anesth. Analg. 112 (6) (2011) 1375–1381.
[22] K. Miyake, M. Iwagami, T. Ohtake, H. Moriya, N. Kume, T. Murata, et al., Association of pre-operative chronic kidney disease and acute kidney injury with in-hospital outcomes of emergency colorectal surgery: a cohort study, World J. Emerg. Surg. 15 (1) (2020) 22.
[23] L.S. Chawla, P.W. Eggers, R.A. Star, P.L. Kimmel, Acute kidney injury and chronic kidney disease as interconnected syndromes, N. Engl. J. Med. 371 (1) (2014) 58–66.
[24] R. Solomon, Improving intravenous fluid therapy for prevention of contrast-induced nephropathy: how to give more without causing heart failure, JACC Cardiovasc. Interv. 9 (1) (2016) 97–99.
[25] N. Wang, L. Jiang, B. Zhu, Y. Wen, X.M. Xi, Fluid balance and mortality in critically ill patients with acute kidney injury: a multicenter prospective epidemiological study, Crit. Care 19 (2015) 371.
[26] P.S. Myles, R. Bellomo, T. Corcoran, A. Forbes, P. Peyton, D. Story, et al., Restrictive versus liberal fluid therapy for major abdominal surgery, N. Engl. J. Med. 378 (24) (2018) 2263–2274.
[27] R. Yang, M. Wolfson, M.C. Lewis, Unique aspects of the elderly surgical population: an anesthesiologist's perspective, Geriatr Orthop Surg Rehabil 2 (2) (2011) 56–64.
[28] F.I. Mahoney, D.W. Barthel, Functional evaluation: the barthel index, Md. State Med. J. 14 (1965) 61–65.
[29] M. Kumar, G.W. Long, M. Major, E. Gates, D.M. Studzinski, R.E. Callahan, et al., Predictors of mortality in nonagenarians undergoing abdominal aortic aneurysm repair: analysis of the National Surgical Quality Improvement Program dataset, J. Vasc. Surg. 75 (4) (2022) 1223–1233.
[30] A. Aslan, T. Atay, N.H. Aydoğan, Risk factors for mortality and survival rates in elderly patients undergoing hemiarthroplasty for hip fracture, Acta Orthop. Traumatol. Turcica 54 (2) (2020) 138–143.