Review

DOI: 10.5582/bst.2023.01208

Neurosurgical perioperative management of frail elderly patients

Xiqi Hu[1,2], Ya-Nan Ma[2,3], Xuemei Jiang[3], Wei Tang[4], Ying Xia[1,*], Peipei Song[2,*]

[1] Department of Neurosurgery, Haikou Affiliated Hospital of Central South University Xiangya School of Medicine Haikou, China;
[2] Center for Clinical Sciences, National Center for Global Health and Medicine, Tokyo, Japan;
[3] Department of Gastroenterology, Hainan Affiliated Hospital of Hainan Medical University, Haikou, China;
[4] International Health Care Center, National Center for Global Health and Medicine, Tokyo, Japan.

SUMMARY With the rapid increase in global aging, the prevalence of frailty is increasing and frailty has emerged as an emerging public health burden. Frail elderly patients suffer from reduced homeostatic reserve capacity, which is associated with a disproportionate decline in physical status after exposure to stress and an increased risk of adverse events. Frailty is closely associated with changes in the volume of the white and gray matter of the brain. Sarcopenia has been suggested to be an important component of frailty, and reductions in muscle strength and muscle mass lead to reductions in physical function and independence, which are critical factors contributing to poor prognosis. Approximately 10–32% of patients undergoing neurological surgery are frail, and the risk of frailty increases with age, which is significantly associated with the occurrence of adverse postoperative events (major complications, total duration of hospitalization, and need for discharge to a nursing facility). The postoperative mortality rate in severely frail patients is 9–11 times higher than that in non-frail individuals. Therefore, due attention must be paid to neurosurgical frailty and muscle assessment in elderly patients. Specialized interventions in the perioperative period of neurosurgery in frail elderly patients may improve their postoperative prognosis.

Keywords sarcopenia, aging, complication, prognosis

1. Introduction

Aging of the population is accelerating rapidly around the world. According to the World Population Prospects (2019 Revision), the number of people age 65 and over around the world exceeded the number of children under 5 for the first time in 2018 and is expected to increase from 9% of the total in 2019 to 16% in 2050; the number of people age 80 and over will increase from 143 million in 2019 to 426 million in 2050 (*1*). Japan, Finland, and Italy are currently the countries with the most serious aging problems (*2*). Aging has become one of the world's most serious medical and social issues. However, the most serious clinical symptom of an aging population is frailty.

In 1994, Rockwood *et al.* summarized frailty in the elderly as an "evolving concept" that has been developing for almost 20 years and is still evolving (*3*). The main characteristics of frailty are reduced function of multiple physiological systems, increased vulnerability to stress, and increased risk of falls, hospitalization, and death (*4*). The global burden of frailty is unknown, mainly because studies of frailty have focused on high-income countries and have used different definitions of frailty (*4*). A systematic evaluation of the prevalence of frailty in community-dwelling older people in several countries, involving a total of 61,500 participants, reported a widely varying prevalence ranging from 4.0% to 59.1%. The overall weighted prevalence of frailty was 10.7%, and the use of different frailty assessment criteria resulted in large differences in prevalence between studies (*5*). Evidence from the Canadian National Population Health Survey shows that the prevalence of frailty increases with age and that higher frailty indices require more health care services (*6*). The Australian and New Zealand Society for Sarcopenia and Frailty Research (ANZSSFR) Expert Working Group recommends that all inpatients age 70 years and older be screened for frailty using a validated tool: the Clinical Frailty Scale (CFS), Hospital Frailty Risk Score (HFSC), a frailty scale, or a frailty index (*7*). The majority of frail older people have sarcopenia, which is considered an important component of frailty due to loss of muscle mass and strength, leading to imbalances and adverse outcomes (*8,9*). The ANZSSFR Expert Working Group recommends that sarcopenia/

muscle loss be assessed in all older (≥ 65 years) inpatients or younger patients with conditions that may increase the risk of sarcopenia, using established criteria (*7*). As the population ages, there has been a corresponding increase in the number of elderly patients undergoing neurosurgery (*10*). Frailty has been shown to be an independent risk factor for neurosurgical outcomes and is a better predictor of patient prognosis than traditional patient age (*11-14*). There is mounting evidence that frailty is strongly associated with a poor prognosis in patients after brain surgery. Frail patients having significantly higher rates of major complications, a longer total duration of hospitalization, a longer length of stay in the intensive care unit, and a higher risk of needing to be transferred to a nursing facility after discharge compared to non-frail patients; the postoperative mortality rate for severely frail patients is 9 to 11 times higher than that for non-frail patients (*11,14-17*). The current review focuses on the assessment and management of perioperative frailty and sarcopenia in elderly neurosurgical patients and it provides possible strategies to reduce the incidence of postoperative adverse events. The flow chart is shown in Figure 1.

2. The definition and etiology of frailty

Frailty is a complex group of age-related clinical conditions that typically involve a decline in the physiological functioning of multiple systems and organs, an increased susceptibility to stress, and a sudden and disproportionate change in health status following a seemingly mildly stressful event such as infection, trauma, or minor surgery. This initial stressful event is usually followed by a long recovery period and an inability to return to previous levels of functioning (*18,19*). The frailty phenotype has five criteria (weakness, slow gait, low physical activity, fatigue, and unintentional weight loss) and is further categorized sequentially as non-frailty (0 criteria), pre-frailty (1–2 criteria), and frailty (≥ 3 criteria) (*20*). Studies have shown that frailty affects approximately 10% of people age 65 years and older, increases with age, and is more common in females than in males (*5*). The development and progression of frailty are influenced by a variety of factors, including sociodemographic, biological, psychological, physical, and lifestyle factors. Sociodemographic factors include age, ethnic background, neighborhood, marital status, and level of education. Psychological factors mainly

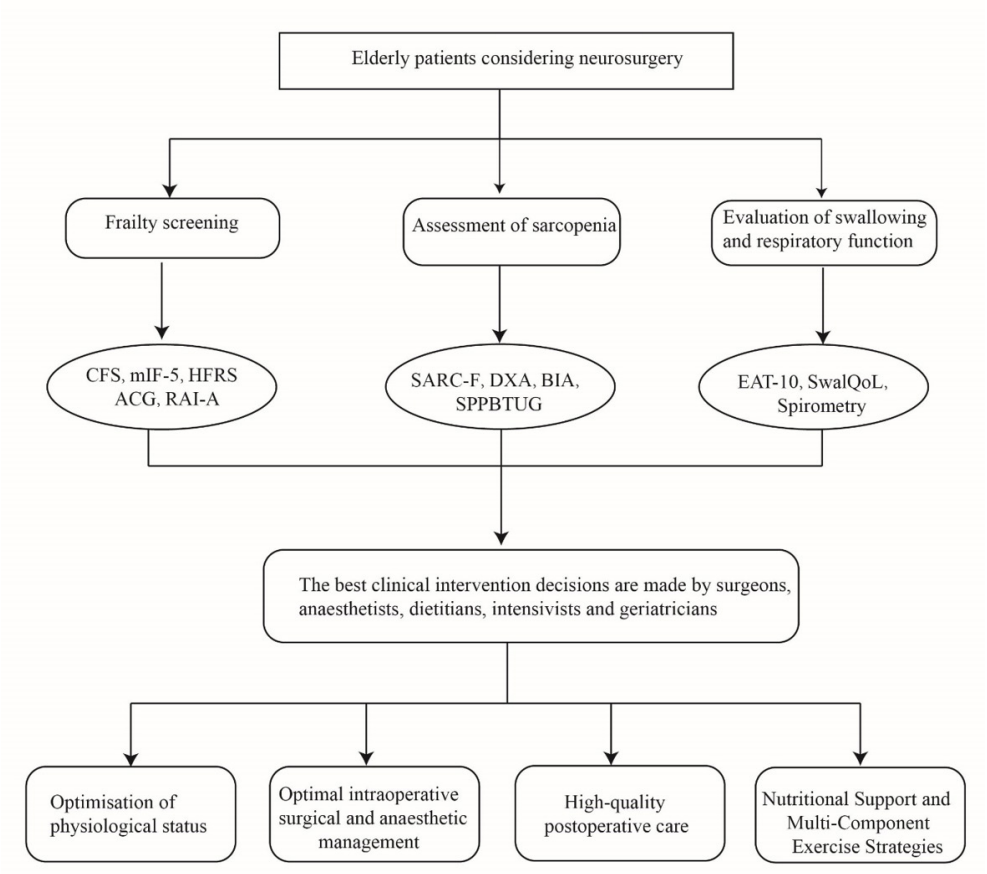

Figure 1. Flowchart of recommendations for elderly patients for the perioperative period of neurosurgery. Abbreviations: ACG, adjusted clinical groups; BIA, bioelectrical impedance analysis; CFS, clinical frailty scale; DXA, dual-energy X-ray absorptiometry; EAT-10, Eating Assessment Tool-10; HFRS, Hospital Frailty Risk Score; mIF-5, Five-factor Modified Frailty Index; RAI-A, Risk Analysis Index-Administrative; SARC-F, Simple Five-item Questionnaire; SPPB, Short Physical Performance Battery; SwalQoL, Swallowing Quality of Life; TUG, timed-up-and-go test.

include depressive states. Lifestyle factors include diet quality and fruit and vegetable intake. Physical factors include chronic diseases (mainly diabetes, obesity, and cardiovascular diseases) and physical inactivity or a sedentary lifestyle (*4,21-23*). In addition, multimorbidity is a risk factor for frailty, leading to imbalances in multiple physiological regulatory systems (*24,25*). According to Heart, stroke and vascular disease-Australian facts, 1.2 million Australians age 18 years and over had one or more conditions related to heart, stroke, or vascular disease in 2017–2018 (*26*). A meta-analysis of multimorbidity and frailty involving a total of 78,122 participants found that the prevalence of multimorbidity among frail people was 72% and the prevalence of frailty among those with multimorbidity was 16% (*27*). The same meta-analysis noted a bidirectional association between multimorbidity and frailty. Emerging evidence suggests that changes in cognitive reserve, or brain reserve, contribute to the development and progression of frailty during the aging process. For example, established features of brain aging – grey matter volume and total white matter hyperintensities – are associated with a wide range of physical and mental health measures (*28-30*). Severity of frailty was correlated with increased total white matter hyperintensities and reduced grey matter volume, particularly in subcortical brain regions, that partially mediated the association between frailty and cognitive decline, poor mental health, and an unhealthy lifestyle (*30*). Resting-state functional MRI data from the Irish Longitudinal Study on Aging (TILDA) showed that Aβ deposition in specific brain regions is associated with worsening frailty in older adults (*31*). Frailty is a category of age-related clinical syndromes influenced by lifestyle, psychological, and physical factors. It is also closely related to changes in brain reserve and structure during aging.

3. The intrinsic link between aging and frailty

Aging is a natural evolutionary process influenced by genetic, environmental, and epigenetic factors. The organism experiences inflammation and endothelial and vascular dysfunction following everyday injuries and infections. The organism repairs the damage at a cellular and tissue level and in the process of repair causes an accumulation of scarring, leading to gradual tissue degeneration and a decline in the physiological reserve function of organs such as the brain, endocrine system, immune system, and skeletal muscles, resulting in frailty and aging (*32-35*). Physiological decline may accelerate as frailty worsens (*36*), leading to deterioration in the functioning of multiple physiological systems that may contribute to a further decline in reserve function. Frail physical status changes disproportionately after exposure to stressful events, leading to an increased risk of adverse outcomes such as falls, delirium, and disability (*35*). In a study of the association between frailty and multi-system physiological disorders in older women, assessment of eight physiological system markers (*e.g.,* anemia, inflammation, and insulin-like growth factor-1) in 1,002 women age 70–79 years found that multi-system physiological abnormalities were a better predictor of frailty than single-system abnormalities. Abnormalities in multiple physiological systems may disrupt the body's homeostasis and adaptive capacity, leading to greater frailty and increased risk of adverse outcomes (*37*). Based on an analysis of data on 37 biomarkers in six physiological systems (lipids, immunity, oxygen transport, liver function, vitamins, and electrolytes) from 33,000 individuals, Li *et al.* found that dysregulation of the homeostasis of multiple systems occurs simultaneously in aging, that no one system is significantly better than another, and that dysregulation of multi-system homeostasis significantly predicts multiple health outcomes, including frailty (*38*). With aging, multiple systems become dysfunctional, function gradually declines, physiological reserves decrease, and the likelihood of frailty increases. However, there is a certain degree of heterogeneity in body function among individuals of the same age (*39*), so one cannot rely solely on age to evaluate the organ reserve capacity of patients. Frailty can better reflect the organ function of patients than age.

4. Sarcopenia and frailty

The concept of sarcopenia was first mentioned in 1988 by Irving Rosenberg, who noted that "no single feature of age-related decline is more striking than the decline in lean body mass, which affects ambulation, mobility, energy intake, overall nutrient intake and status, independence, and breathing" (*40*). In 2016, the World Health Organization (WHO) recognized sarcopenia as a separate disease, code M62.84 in the ICD-10-CM (*41*). The European Working Group on Sarcopenia in the Elderly (EWGSOP) defines sarcopenia as a syndrome characterized by progressive and systemic loss of skeletal muscle mass and strength, with a risk of adverse outcomes such as physical disability, poor quality of life (QoL), and death (*8*). The diagnostic criteria for sarcopenia are low muscle mass and strength or low physical performance (*8*). Sarcopenia is present in the majority of frail older people and is due to a progressive and systemic loss of skeletal muscle strength and mass with age (*8,9*). Many factors contribute to sarcopenia, including the body's normal aging process, the effects of early physical development, a bedridden or sedentary lifestyle, poor diet, chronic diseases, and medications (*8*). The five criteria for the frailty phenotype are strongly associated with sarcopenia, which has been described as the biological substrate of frailty (*42-44*). There is a growing body of evidence for endocrine dysfunction in frail patients. Deficiencies of certain hormones in the body are associated with loss of muscle mass (*8*).

A study on the health and aging of women, in which serum levels of total insulin-like growth factor-1 (IGF-1), dehydroepiandrosterone sulfate, and free testosterone were examined in relation to frailty status (non-frail, prefrail, or frail) in 494 women age 70–79 years, found that individuals with anabolic hormonal deficiency were more likely to be frail, suggesting that frailty syndromes may involve systemic endocrine disruption (*45*). In a study of 214 older adults age 80–90 years, higher cortisol levels and delayed circadian variation were observed in frail older women (*46*). Cortisol promotes myogenic fiber degradation and inhibits protein synthesis to stimulate muscle atrophy (*18*), further contributing to sarcopenia syndrome. Insulin-like growth factors (IGFs) are a class of small peptides that increase the anabolic activity of many cells, with particularly important roles in neuronal plasticity and skeletal muscle strength (*47*). IGFs increase muscle strength by stimulating an increase in myoblast production, activating muscle cell hypertrophy, and inhibiting muscle proteolysis (*18*,*48*), while secretion of IGFs decreases in frail patients (*45*). By directly stimulating androgen receptors in skeletal muscle and activating the IGF-1 signaling pathway, testosterone increases muscle contractile protein synthesis (*49*). Research has shown that testosterone levels decline with age, and data suggest that bioavailable testosterone declines at a rate of approximately 2% per year in middle-aged men (*50*). Several epidemiological studies that have reported that low testosterone is associated with frailty (*51,52*). In addition, the production of vitamin D, the thyroid hormone, has also been shown to be involved in frailty and sarcopenia (*53,54*). Frailty and sarcopenia are closely related. On the one hand, sarcopenia is the biological basis of frailty, and on the other hand, the effects on endocrine hormones during the development and progression of frailty can further exacerbate sarcopenia.

5. Post-neurosurgical complications in frail patients

Frailty is strongly associated with the occurrence of adverse clinical outcomes after surgery, and frail patients have an increased risk of complications and mortality after surgery (*55*). Frailty is associated with increased mortality in patients after surgery. A cohort study of 432,828 patients suggested that low- and moderate-stress procedures may be risky in both frail and very frail patients, who had high rates of postoperative mortality (*55*). In neurosurgery, there is growing evidence that the presence of preoperative symptoms of frailty is significantly associated with a higher incidence of adverse events after neurosurgery (*12,56*). Based on data from the National Inpatient Sample (NIS), a retrospective study found that patients diagnosed with subarachnoid hemorrhage or cerebral hemorrhage who underwent surgery for aneurysm repair between 2005 and 2014 had an overall prevalence of preoperative frailty of 11.2% and that frail patients had an increased risk of postoperative tracheotomy, gastrostomy tube placement, and associated complications (*12*). Multivariate analysis showed that frailty was strongly associated with an increased risk of postoperative complications (aOR: 3.29, 95% CI: 2.55–4.25) and an increased risk of discharge to institutional care (aOR 2.50, 95% CI: 2.10–2.97) (*12*). Using the National Surgical Quality Improvement Program (NSQIP) database (2015–2019), Cole *et al.* found that 14.6% of patients who underwent resection of intracranial meningiomas (n = 5,818) were frail according to a five-factor modified frailty index (mFI-5) ≥ 2. Of these, 12.8% were generally frail and 1.8% were severely frail ((mFI-5) ≥ 3). In addition, severely frail patients had an increased risk of death (OR: 11.17, 95% CI: 3.45–36.19), a higher rate of complications (OR: 4.37, 95% CI: 2.68–7.12), and a longer duration of hospitalization (OR: 4.28, 95% CI: 2.74–6.68) compared to non-frail patients (*13*). The same study showed that the odds ratio (OR) and effect sizes of increasing frailty grade are better predictors of prognosis than age. Tang *et al.* retrospectively analyzed data on patients who underwent microsurgery for cerebral arteriovenous malformations (AVM) nationwide from 2002–2017, and they identified a new predictor of frailty, the AVM-5. They then compared the AVM-5 to the 5-factor modified frailty index (mFI), the 11-factor modified frailty index (mFI-11), and the Charlson comorbidity index (CCI). Frail admissions were predicted at a rate of 32% by the AVM-5, 8.3% by the mFI-5, 14.3% by the mFI-11, and 20.8% by the CCI. In addition, the frailty predictor AVM-5 was superior to other indicators in predicting major complications, postoperative mortality, and the total duration of hospitalization in microsurgery for cerebral arteriovenous malformations (*14*). Therefore, the mFI-5, mFI-11, and CCI can be used as complements to assess frailty in patients undergoing microsurgery for arteriovenous malformations, although the AVM-5 has some advantages over age and the mFI-5, mFI-11, and CCI. Frail patients with traumatic brain injury (TBI) had higher morbidity and mortality rates from complications compared to non-frail patients with traumatic intracranial hemorrhage according to an analysis of data from 691,821 TBI patients enrolled in the National Trauma Database (NTD) between 2007 and 2017 (*56*). A large multi-center data review evaluating the independent impact of frailty on brain tumor resection (BTR) showed that higher scores on the Risk Analysis Index-Administrative (RAI-A) were associated with an increased risk of adverse outcomes, including in-hospital mortality, non-routine discharge, and major complications (*11*). The RAI-A is considered to be a useful tool for the preoperative risk assessment of brain tumor patients and can be used as a basis for the risk-benefit assessment of brain tumor resection. Current studies have demonstrated that frail patients undergoing various types of neurosurgery have a significantly

Table 1. The effect of frailty on patients after neurosurgery

Reference	Disease	Mean age (years)	Method	Criteria	Frailty (%)	Postoperative adverse outcomes (frail *vs.* non-frail group)			
						Frailty Score	Outcome	OR	95% CI
Tang *et al.* (*56*)	TBI	57.6	mFI-5	mFI-5 ≥ 2	18	mFI-5 ≥ 2	in-hospital mortality	1.36	1.32–1.39
							major complication	1.06	1.04–1.07
							ICU LOS	1.11	1.10–1.12
							total LOS	1.13	1.11–1.14
Guo *et al.* (*12*)	aSAH	54.8	ACG	ACG ≥1	11.2	ACG ≥1	major complication	3.29	2.55–4.25
							discharged to institutional care	2.5	2.10–2.97
							in-hospital mortality	0.4	0.33–0.49
Thommen *et al.* (*11*)	BT	59	RAI-A	RAI-A >25	28.7	RAI-A 41–45	in-hospital mortality	4.3	2.1–8.9
							major complication	2.2	1.6–3.0
						RAI-A >45	in-hospital mortality	9.5	3.9–22.9
							major complication	2.5	1.5–4.1
Huq *et al.* (*60*)	BT	55.5	mFI-5	mFI-5 ≥ 2	19	mFI-5 ≥ 2	total LOS	1.38	0.96–1.80
							respiratory failure	1.55	1.01–2.40
							physiological/metabolic derangement	3.66	2.13–6.28
Cole *et al.* (*13*)	Meningioma	59	mFI-5	mFI-5 ≥ 2	14.6	mFI-5 ≥3	in-hospital mortality	11.17	3.45–36.19
							major complication	4.15	2.46–6.99
							eLOS	4.28	2.74–6.68
Jimenez *et al.* (*16*)	BT	55.3	HFRS	HFRS >15	8.2	HFRS >15	Non-routine discharge	1.14	1.12–1.17
							major complication	1.14	1.11–1.17
							90-day mortality	1.03	0.99–1.08

Abbreviations: ACG, adjusted clinical groups; aSAH, aneurysmal subarachnoid hemorrhage; BTR, brain tumor resection; eLOS, extended length of stay in hospital; HFRS, Hospital Frailty Risk Score; ICU, intensive care unit; mFI-5, Five-factor Modified Frailty Index; OR, odds ratio; RAI-A, Risk Analysis Index-Administrative; TBI, traumatic brain injury.

increased risk of a poor postoperative prognosis, as shown in Table 1. Frailty is a dynamic process. In frail patients undergoing neurosurgery, symptoms of frailty may be exacerbated, leading to an increased risk of complications and death. Conducting a preoperative assessment of frailty in neurosurgical patients and improving the perioperative management of frail patients will help to reduce the incidence of adverse events and improve prognosis for patients.

6. Management of postoperative frailty in neurosurgery

6.1. Frailty combined with biological age

With the aging of the world's population, a number of clinical studies have been conducted to investigate the relationship between actual age and various clinical outcomes, including surgery. A correlation between biological age and poor clinical prognosis is corroborated by a large amount of data. However, physiologic age is an immutable risk factor with obvious limitations as a study variable, so it should not be used as the sole determinant in making surgical decisions (*13,56,57*). In recent years, evidence has increasingly revealed that poor prognosis is related not only to the patient's age but also to the patient's level of frailty. The days of age being the sole determinant of outcome are over, and a patient's level of frailty should be part of the clinical decision-making process (*57,58*). Although there is no uniform assessment strategy for frailty, the finding that frail patients are more likely to experience adverse events postoperatively is consistent among studies (*14,59-61*). In a correlative study of 980 elderly oncology patients (age ≥ 75 years) who underwent a preoperative comprehensive geriatric assessment (CGA), frailty (stratified by the number of impairments in the geriatric assessment) was associated with 6-month mortality after surgery (OR: 1.14 for each unit increase in the CGA score; $p = 0.01$) (*62*). Another study of the impact of frailty on clinical outcomes after aneurysmal subarachnoid hemorrhage found that frailty was significantly associated with an increased risk of postoperative tracheostomy or gastrostomy tube placement and of postoperative complications. A risk-stratified analysis of patients undergoing surgery found that postoperative effects were more pronounced in frail patients under the age of 65 years (*12*). Another study on the association between frailty status and age and outcomes in patients undergoing surgery for intracranial meningiomas showed that increasing frailty was a better predictor of adverse postoperative outcomes than age, based on the OR and effect size (*13*). An assessment of frailty should be performed in elderly patients being considered for neurosurgery, rather than simply considering the actual age of the patient.

6.2. Outpatient screening of elderly patients for frailty and sarcopenia

Frailty and sarcopenia screening tools can help surgeons assess their patients' frailty and muscle status in a timely manner in an outpatient setting. Currently, the

CFS (*63*), Hospital Frailty Risk Score (HFRS) (*64*), CGA (*65*), frailty indices such as the 11-factor and 5-factor modified frailty indices (mFI-11 and mFI-5) (*66*), and the Risk Analysis Index (RAI) (*11*) are commonly used as screening indices to assess frailty in neurosurgery. Because of its simplicity and ease of use, the CFS is generally used in community settings. However, the HFRS is the most widely used screening index in the acute phase of the disease. The CGA-derived frailty index is commonly used to screen frail patients in population screening. The RAI has been shown to be a useful predictor of postoperative prognosis in neurosurgical patients and has been shown to be a particularly effective predictor of mortality. Jimenez *et al.* used the HFRS to predict postoperative outcomes in 2,518 patients with intracranial tumors and found that the HFRS was significantly and independently associated with postoperative complications (OR: 1.14, $p < 0.0001$), duration of hospitalization (coefficient = 0.50, $p < 0.0001$), increased hospital expenses (coefficient = 1,917.49, $p < 0.0001$), nonroutine discharge (OR: 1.14, $p < 0.0001$), and 90-day readmission (OR: 1.06, $p < 0.0001$) (*16*). Therefore, the HFRS is considered to be a valid predictor of postoperative outcomes in patients with intracranial tumors. Different frailty screening indicators have different effects on the assessment of frailty. Recent clinical studies have confirmed that the American Society of Anesthesiologists (ASA) score and the modified CCI have better predictive ability in preoperative risk stratification for spinal tumor surgery. In addition, the HFRS effectively predicts major postoperative complications and total duration of hospitalization in patients with intracranial tumors. However, the CFS is highly applicable in predicting overall survival in patients after resection of high-grade gliomas. The mFI-5 has been shown to be a valid indicator of frailty in patients with TBI and internal hemorrhage. The AVM-5 is significantly superior to other screening criteria in the microsurgical evaluation of arteriovenous malformations. The RAI-A has a higher predictive power for postoperative mortality in frail patients compared to other assessment measures (*11,14-16,56,67*).

Sarcopenia and frailty are related and there is a partial overlap between the two. This is especially true in terms of the parameter of impaired physical functioning, which is present in close to half of frail patients (*41,68*). Muscle tissue loss is inevitable in neurosurgical patients on postoperative bed rest, and it is most rapid initially due to inactivity (*69-71*). Trappe *et al.* reported a 29% reduction in the volume of the quadriceps muscle in young women after 21 days of bed rest (*72*). Preoperative evaluation of sarcopenia (loss of muscle mass and strength) is necessary in neurosurgical patients. This is in line with the recommendations of the ANZSSFR Expert Working Group to assess sarcopenia in inpatients age 65 years and older in a hospital setting. The EWGSOP2 recommends a pathway of "detection-assessment-confirmation-condition" (*73*) for assessing the presence of sarcopenia in clinical settings, where patients with sarcopenia are first identified with the SARC-F questionnaire, then assessed with the chair stand test, muscle quantity or quality is subsequently confirmed with dual energy X-ray absorptiometry (DXA) or bioelectric impedance analysis (BIA), and patients are finally further assessed for physical function status (*41,73*). Assessment of sarcopenia and related scales are shown in Table 2 (*73*). Patients with cranial tumors also need to be assessed for respiratory and swallowing function. Respiratory complications such as aspiration pneumonia and pulmonary infection are most common in debilitated

Table 2. Tools for the diagnosis and general assessment of sarcopenia

Criteria	Evaluation instruments	Cut-off points for sarcopenia	
		Cut-off points for men	Cut-off points for women
i) Low muscle strength	SARC-F questionnaire screening, Chair stand test, Grip strength	Chair stand > 15 s for five rises, Grip strength < 27 kg	Grip strength < 16 kg
ii) Low muscle quantity or quality	Appendicular skeletal muscle mass (ASMM) measured with dual energy X-ray absorptiometry (DXA), Total body skeletal muscle mass (SMM) or ASMM predicted with bioelectric impedance analysis (BIA), Cross-sectional area of the lumbar spine muscle according to CT or MRI	ASMM < 20 kg, ASMM/ height^2 < 7.0 kg/m^2	ASMM < 15 kg, ASMM/ height^2 < 5.5 kg/m^2
iii) Low physical performance	Gait speed (NIH Toolbox 4-meter Walk Gait Speed Test), Short Physical Performance Battery (SPPB), Timed-up-and-go test (TUG), 400-meter walk or long-distance corridor walk (400-m walk)	Gait speed ≤ 0.8 m/s, 400-m walk non-completion, 400-m walk ≥ 6 min for completion	SPPB ≤ 8 points, TUG ≥ 20 s, 400-m walk non-completion, 400-m walk ≥ 6 min for completion

Criterion *i*) identifies probable sarcopenia. Additional documentation of criterion *ii*) confirms the diagnosis. Sarcopenia is considered severe when criteria *i*), *ii*), and *iii*) are all met.

postoperative patients; dysphagia is a major cause of serious postoperative complications. Preoperative respiratory and swallowing dysfunction are significantly associated with early postoperative complications and mortality in neurosurgical patients (*74,75*). Respiratory function can be assessed by pulmonary function and swallowing function is screened for with the Eating Assessment Tool-10 (EAT-10) or the Swallowing Quality of Life (SwalQoL) questionnaire (*76-78*). Screening and assessment of frailty, sarcopenia, swallowing, and respiratory function prior to neurosurgery in elderly patients can help medical staff, patients, and their caregivers to formulate a rational and individualized treatment plan.

6.3. Perioperative management of frail patients

Frail patients who have undergone neurosurgery have a higher risk of short- and long-term complications as well as a higher mortality rate. Common complications in these patients include somatic complications and functional and cognitive decline (*78*). Surgical management facilitates the improvement of patients' surgical success and reduces the incidence of complications and mortality. The management process mainly includes frailty screening, optimization of physiological status, preoperative assessment, intraoperative management, and postoperative management in a community nursing program (CNP) as shown in Figure 2. New guidelines for the perioperative care of frail patients undergoing elective and emergency surgery from the Centre for Perioperative Care and the British Geriatrics Society (2021) recommend that all patients with a CFS ≥ 5 should undergo CGA and optimization prior to surgery (*79*). Optimization of physiologic status generally includes smoking cessation, inspiratory muscle training,

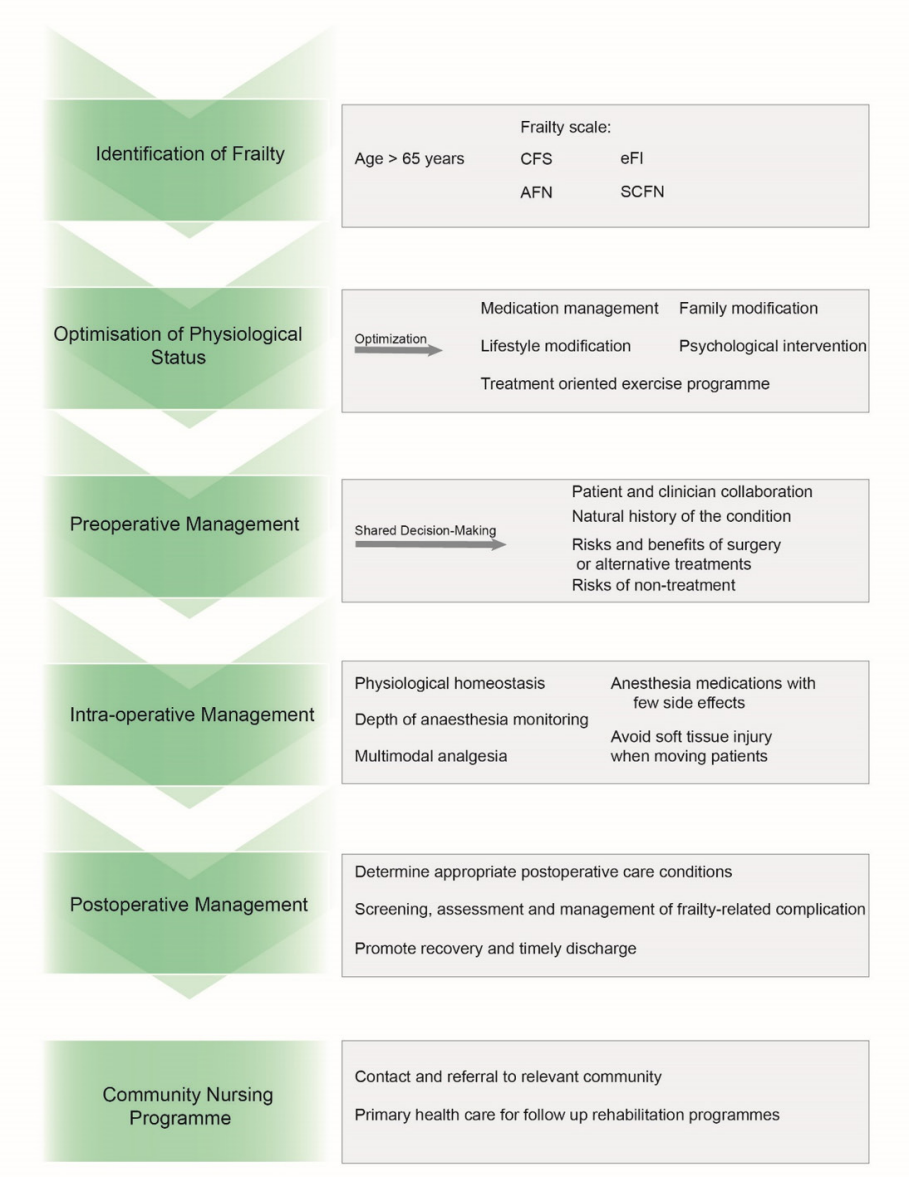

Figure 2. Guidelines for perioperative treatment of frail patients. Abbreviations: AFN, acute frailty network; eFI, electronic frailty index; CFS, clinical frailty scale; CNP, community nursing program; SDM, shared decision-making; SCFN, specialized clinical frailty network.

exercise, and physical therapy. Studies have shown that smoking cessation and inspiratory muscle training in patients with shortness of breath can reduce the duration of hospitalization after routine surgery. In addition, nutritional rehabilitation under the guidance of a dietician is beneficial to optimize the physiological state of patients with malnutrition and loss of appetite. Cognitive-behavioral therapy may be appropriate for patients with excessive anxiety or diminished cognitive function. Moreover, reducing sedentary behavior, regular sitting and standing exercises, and short walks can help improve exercise tolerance (*79-81*). The decision to proceed with surgery in a frail patient requires the involvement of the patient, family, and clinician in the decision-making process, including discussion of the natural progression of the disease, the advantages and disadvantages of surgery or alternative therapies, and the consequences of not undergoing treatment (*82*). In order to make the best medical decision for each individual at any given time, the best medical evidence available needs to be consulted (*83*). During surgery and anesthesia, particular attention needs to be paid to maintaining the balance of indicators in frail patients, such as the use of the lowest effective dose of anesthetics, the use of multimodal analgesia to reduce postoperative pain and minimize adverse reactions (*84,85*). Impaired skeletal muscle and skin function is partially associated with frailty during surgery, so soft tissue injury should be avoided during the procedure, and especially when moving the patient. In addition, manual handling and gel decompression support should be used to facilitate postural immobilization and avoid movement beyond the patient's normal range of motion (*79,86*). Furthermore, opioid analgesics should be used as appropriate during the perioperative period, and anticholinergic exposure should be minimized to reduce the risk of delirium (*84*). Reassessment after surgery is necessary to determine whether a frail patient needs intensive care or transfer to a specialized intensive care unit after surgery, and quality postoperative care and postoperative rehabilitation should be provided to the frail patient on a case-by-case basis (*87-89*). Patient-related postoperative complications, including delirium, deterioration of somatic function, falls, and pulmonary infections, need to be predicted, prevented, recognized, and managed in frail patients postoperatively (*90,91*). Early postoperative removal of unnecessary tubes and catheters, support for patients to sit up and move around, and assistance with regular orientation including the provision of hearing aids, eyeglasses, and nutritional support are needed (*79,92-94*). Obstacles to discharge for frail patients need to be recognized and resolved as early as possible in discharge plans, and discussing and recording the patient's anticipated rehabilitation and follow-up needs is important. More importantly, special attention needs to be paid to the post-discharge rehabilitation and care of older frail patients (*79*).

7. Management strategies for sarcopenia

Sarcopenia in elderly patients is primarily prevented during hospitalization with high-protein, multi-nutrient nutritional support and multi-component exercise strategies to prevent loss of muscle mass and maintain physical function and health-related QoL. As recommended by the ANZSSFR Expert Working Group, older patients identified as having sarcopenia or frailty should be assessed and tested by a dietician to determine appropriate nutritional support (*7*). According to the European Society for Clinical Nutrition and Metabolism (ESPEN) recommendations, the basic energy requirement for inpatients should be 30 kcal/kg/day, and the basic requirement for protein should be 1.2 g/kg/day, adjusted according to the actual condition of the patient (*e.g.,* obesity or in critical condition) (*95*). A study has shown that high-protein supplementation was associated with reduced muscle loss and a lower incidence of malnutrition during hospital discharge (*96*). The ESPEN recommends that older adults, including those with sarcopenia and/or frailty, should undergo a multicomponent exercise program prescribed and supervised by a qualified health care professional as early as possible, including resistance, challenging balance, and functional training that can safely and effectively prevent functional decline during hospitalization (*96*). There is insufficient evidence to recommend any drug therapy for sarcopenia or frailty.

8. Conclusion

Inadequate awareness of frailty and sarcopenia in older patients by health care personnel can affect their ability to make appropriate surgical decisions for their patients. Overestimation of surgical risk may result in patients missing the best opportunity for surgery, while underestimation of surgical risk may expose patients to unnecessary risk. Screening for frailty may help predict postoperative complications and prognosis in elderly patients undergoing neurosurgery. In addition, screening patients for frailty and sarcopenia in a clinical setting can help formulate individualized care strategies to meet the complex needs of different patients. Unfortunately, there is a lack of standardized frailty assessment criteria, and the predictive efficacy of frailty prediction tools varies widely under the same conditions. Further research needs to be conducted on frailty assessment strategies in patients undergoing neurosurgery, and a multidisciplinary assessment involving surgeons, anesthesiologists, intensivists, and geriatricians should be conducted to formulate the most appropriate management strategies. Based on the findings of the current review, proactive interventions for elderly frail patients are likely to improve postoperative recovery and patient QoL, with promising real-world applications.

Funding: This work was supported by a grant from the 2023 Foreign Experts Program in Hainan Province (SQ2023WGZJ0002) and the Hainan Provincial Center for Clinical Medical Research on Cerebrovascular Disease (No. LCYX202107).

Conflict of Interest: The authors have no conflicts of interest to disclose.

References

1. United Nations. Trends in population ageing. *https://www.un.org/en/global-issues/ageing* (accessed August 1, 2023).
2. OECD iLibrary. Elderly population. *https://doi.org/10.1787/8d805ea1-en* (accessed August 1, 2023)
3. Rockwood K, Fox RA, Stolee P, Robertson D, Beattie BL. Frailty in elderly people: An evolving concept. CMAJ. 1994; 150:489-495.
4. Hoogendijk EO, Afilalo J, Ensrud KE, Kowal P, Onder G, Fried LP. Frailty: Implications for clinical practice and public health. Lancet. 2019; 394:1365-1375.
5. Collard RM, Boter H, Schoevers RA, Oude Voshaar RC. Prevalence of frailty in community-dwelling older persons: A systematic review. J Am Geriatr Soc. 2012; 60:1487-1492.
6. Rockwood K, Song X, Mitnitski A. Changes in relative fitness and frailty across the adult lifespan: Evidence from the Canadian National Population Health Survey. CMAJ. 2011; 183:E487-E494.
7. Daly RM, Iuliano S, Fyfe JJ, Scott D, Kirk B, Thompson MQ, Dent E, Fetterplace K, Wright ORL, Lynch GS, Zanker J, Yu S, Kurrle S, Visvanathan R, Maier AB. Screening, diagnosis and management of sarcopenia and frailty in hospitalized older adults: Recommendations from the Australian and New Zealand Society for Sarcopenia and Frailty Research (ANZSSFR) expert working group. J Nutr Health Aging. 2022; 26:637-651.
8. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, Martin FC, Michel JP, Rolland Y, Schneider SM, Topinková E, Vandewoude M, Zamboni M; European Working Group on Sarcopenia in Older People. Sarcopenia: European consensus on definition and diagnosis: Report of the European working group on sarcopenia in older people. Age aging. 2010; 39:412-423.
9. Howard C, Ferrucci L, Sun K, Fried LP, Walston J, Varadhan R, Guralnik JM, Semba RD. Oxidative protein damage is associated with poor grip strength among older women living in the community. J Appl Physiol (1985). 2007; 103:17-20.
10. Deorah S, Lynch CF, Sibenaller ZA, Ryken TC. Trends in brain cancer incidence and survival in the United States: Surveillance, epidemiology, and end results program, 1973 to 2001. Neurosurg Focus. 2006; 20:E1.
11. Thommen R, Kazim SF, Rumalla K, Kassicieh AJ, Kalakoti P, Schmidt MH, McKee RG, Hall DE, Miskimins RJ, Bowers CA. Preoperative frailty measured by risk analysis index predicts complications and poor discharge outcomes after brain tumor resection in a large multi-center analysis. J Neurooncol. 2022; 160:285-297.
12. Guo Y, Wu H, Sun W, Hu X, Dai J. Effects of frailty on postoperative clinical outcomes of aneurysmal subarachnoid hemorrhage: Results from the national inpatient sample database. BMC Geriatr. 2022; 22:460.
13. Cole KL, Kazim SF, Thommen R, Alvarez-Crespo DJ, Vellek J, Conlon M, Tarawneh OH, Dicpinigaitis AJ, Dominguez JF, McKee RG, Schmidt MH, Couldwell WT, Cole CD, Bowers CA. Association of baseline frailty status and age with outcomes in patients undergoing intracranial meningioma surgery: Results of a nationwide analysis of 5,818 patients from the National Surgical Quality Improvement Program (NSQIP) 2015-2019. Eur J Surg Oncol. 2022; 48:1671-1677.
14. Tang OY, Bajaj AI, Zhao K, Liu JK. Patient frailty association with cerebral arteriovenous malformation microsurgical outcomes and development of custom risk stratification score: An analysis of 16,721 nationwide admissions. Neurosurg Focus. 2022; 53:E14.
15. Klingenschmid J, Krigers A, Pinggera D, Kerschbaumer J, Thome C, Freyschlag CF. The Clinical Frailty Scale as predictor of overall survival after resection of high-grade glioma. J Neurooncol. 2022; 158:15-22.
16. Jimenez AE, Liu J, Cicalese KV, Jimenez MA, Porras JL, Azad TD, Jackson C, Gallia GL, Bettegowda C, Weingart J, Mukherjee D. A comparative analysis of the Hospital Frailty Risk Score in predicting postoperative outcomes among intracranial tumor patients. J Neurosurg. 2022;1-10.
17. Galimberti S, Graziano F, Maas AIR, Isernia G, Lecky F, Jain S, Sun X, Gardner RC, Taylor SR, Markowitz AJ, Manley GT, Valsecchi MG, Bellelli G, Citerio G; CENTER-TBI and TRACK-TBI participants and investigators. Effect of frailty on 6-month outcome after traumatic brain injury: A multicentre cohort study with external validation. Lancet Neurol. 2022; 21:153-162.
18. Clegg A, Hassan-Smith Z. Frailty and the endocrine system. Lancet Diabetes Endocrinol. 2018; 6:743-752.
19. Dent E, Martin FC, Bergman H, Woo J, Romero-Ortuno R, Walston JD. Management of frailty: Opportunities, challenges, and future directions. Lancet. 2019; 394:1376-1386.
20. Fried LP, Tangen CM, Walston J, Newman AB, Hirsch C, Gottdiener J, Seeman T, Tracy R, Kop WJ, Burke G, McBurnie MA; Cardiovascular Health Study Collaborative Research Group. Frailty in older adults: Evidence for a phenotype. J Gerontol A Biol Sci Med Sci. 2001; 56:M146-M156.
21. Feng Z, Lugtenberg M, Franse C, Fang X, Hu S, Jin C, Raat H. Risk factors and protective factors associated with incident or increase of frailty among community-dwelling older adults: A systematic review of longitudinal studies. PLoS One. 2017; 12:e0178383.
22. Kim N, Kim GS, Won CW, Lee JJ, Park MK, Shin J, Kim M. Two-year longitudinal associations between nutritional status and frailty in community-dwelling older adults: Korean frailty and aging cohort study. BMC Geriatr. 2023; 23:216.
23. Rodriguez-Manas L, Rodriguez-Sanchez B, Carnicero JA, Rueda R, Garcia-Garcia FJ, Pereira SL, Sulo S. Impact of nutritional status according to GLIM criteria on the risk of incident frailty and mortality in community-dwelling older adults. Clin Nutr. 2021; 40:1192-1198.
24. Fried LP, Ferrucci L, Darer J, Williamson JD, Anderson G. Untangling the concepts of disability, frailty, and comorbidity: Implications for improved targeting and care. J Gerontol A Biol Sci Med Sci. 2004; 59:255-263.
25. Hanlon P, Nicholl BI, Jani BD, Lee D, McQueenie R, Mair FS. Frailty and pre-frailty in middle-aged and older adults and its association with multimorbidity and

mortality: A prospective analysis of 493737 UK Biobank participants. Lancet Public Health. 2018; 3:e323-e332.
26. Australian Institute of Health and Welfare. Heart, stroke and vascular disease: Australian facts. *https://www.aihw.gov.au/reports/heart-stroke-vascular-diseases/hsvd-facts/contents/all-heart-stroke-and-vascular-disease* (accessed August 1, 2023)
27. Vetrano DL, Palmer K, Marengoni A, Marzetti E, Lattanzio F, Roller-Wirnsberger R, Lopez Samaniego L, Rodríguez-Mañas L, Bernabei R, Onder G, Joint Action ADVANTAGE WP4 Group. Frailty and multimorbidity: A systematic review and meta-analysis. J Gerontol A Biol Sci Med Sci. 2019; 74:659-666.
28. Zijlmans JL, Lamballais S, Lahousse L, Vernooij MW, Ikram MK, Ikram MA, Luik AI. The interaction of cognitive and brain reserve with frailty in the association with mortality: An observational cohort study. Lancet Healthy Longev. 2021; 2:e194-e201.
29. Chen WT, Chou KH, Liu LK, Lee PL, Lee WJ, Chen LK, Wang PN, Lin CP. Reduced cerebellar gray matter is a neural signature of physical frailty. Hum Brain Mapp. 2015; 36:3666-3676.
30. Jiang R, Noble S, Sui J, Yoo K, Rosenblatt M, Horien C, Qi S, Liang Q, Sun H, Calhoun VD, Scheinost D. Associations of physical frailty with health outcomes and brain structure in 483033 middle-aged and older adults: A population-based study from the UK Biobank. Lancet Digit Health. 2023; 5:e350-e359.
31. Zuniga RG, Davis JRC, Boyle R, De Looze C, Meaney JF, Whelan R, Kenny RA, Knight SP, Ortuno RR. Brain connectivity in frailty: Insights from The Irish Longitudinal Study on Aging (TILDA). Neurobiol Aging. 2023; 124:1-10.
32. Thuault S. Reflections on aging research from within the National Institute on Aging. Nat Aging. 2021; 1:14-18.
33. Kemoun P, Ader I, Planat-Benard V, *et al.* A gerophysiology perspective on healthy aging. aging Res Rev. 2022; 73:101537.
34. Angulo J, El Assar M, Rodriguez-Manas L. Frailty and sarcopenia as the basis for the phenotypic manifestation of chronic diseases in older adults. Mol Aspects Med. 2016; 50:1-32.
35. Clegg A, Young J, Iliffe S, Rikkert MO, Rockwood K. Frailty in elderly people. Lancet. 2013; 381:752-762.
36. Ferrucci L, Cavazzini C, Corsi A, Bartali B, Russo CR, Lauretani F, Ferrucci L, Cavazzini C, Corsi AM, Bartali B, Russo CR, Lauretani F, Bandinelli S, Bandinelli S, Guralnik JM. Biomarkers of frailty in older persons. J Endocrinol Invest. 2002; 25:10-15.
37. Fried LP, Xue QL, Cappola AR, Ferrucci L, Chaves P, Varadhan R, Guralnik JM, Leng SX, Semba RD, Walston JD, Blaum CS, Bandeen-Roche K. Nonlinear multisystem physiological dysregulation associated with frailty in older women: Implications for etiology and treatment. J Gerontol A Biol Sci Med Sci. 2009; 64:1049-1057.
38. Li Q, Wang S, Milot E, Bergeron P, Ferrucci L, Fried LP, Cohen AA. Homeostatic dysregulation proceeds in parallel in multiple physiological systems. Aging Cell. 2015; 14:1103-1112.
39. Gordon EH, Hubbard RE. Frailty: Understanding the difference between age and aging. Age aging. 2022; 51.
40. Rosenberg IH. Sarcopenia: Origins and clinical relevance. J Nutr. 1997; 127:990S-991S.
41. Cao L, Morley JE. Sarcopenia is recognized as an independent condition by an international classification of disease, tenth revision, clinical modification (ICD-10-CM) Code. J Am Med Dir Assoc. 2016; 17:675-677.
42. Landi F, Calvani R, Cesari M, Tosato M, Martone AM, Bernabei R, Onder G, Marzetti E. Sarcopenia as the biological substrate of physical frailty. Clin Geriatr Med. 2015; 31:367-374.
43. Cesari M, Landi F, Vellas B, Bernabei R, Marzetti E. Sarcopenia and physical frailty: Two sides of the same coin. Front Aging Neurosci. 2014; 6:192.
44. Davies B, Garcia F, Ara I, Artalejo FR, Rodriguez-Manas L, Walter S. Relationship between sarcopenia and frailty in the Toledo study of healthy aging: A population based cross-sectional study. J Am Med Dir Assoc. 2018; 19:282-286.
45. Cappola AR, Xue QL, Fried LP. Multiple hormonal deficiencies in anabolic hormones are found in frail older women: The women's health and aging studies. J Gerontol A Biol Sci Med Sci. 2009; 64:243-248.
46. Varadhan R, Walston J, Cappola AR, Carlson MC, Wand GS, Fried LP. Higher levels and blunted diurnal variation of cortisol in frail older women. J Gerontol A Biol Sci Med Sci. 2008; 63:190-195.
47. Florini JR, Ewton DZ, Magri KA. Hormones, growth factors, and myogenic differentiation. Annu Rev Physiol. 1991; 53:201-216.
48. Leng SX, Hung W, Cappola AR, Yu Q, Xue QL, Fried LP. White blood cell counts, insulin-like growth factor-1 levels, and frailty in community-dwelling older women. J Gerontol A Biol Sci Med Sci. 2009; 64:499-502.
49. Afilalo J. Androgen deficiency as a biological determinant of frailty: Hope or hype? J Am Geriatr Soc. 2014; 62:1174-1178.
50. Feldman HA, Longcope C, Derby CA, Johannes CB, Araujo AB, Coviello AD, Bremner WJ, McKinlay JB. Age trends in the level of serum testosterone and other hormones in middle-aged men: Longitudinal results from the Massachusetts male aging study. J Clin Endocrinol Metab. 2002; 87:589-598.
51. Eichholzer M, Barbir A, Basaria S, Dobs AS, Feinleib M, Guallar E, Menke A, Nelson WG, Rifai N, Platz EA, Rohrmann S. Serum sex steroid hormones and frailty in older American men of the Third National Health and Nutrition Examination Survey (NHANES III). Aging Male. 2012; 15:208-215.
52. Mohr BA, Bhasin S, Kupelian V, Araujo AB, O'Donnell AB, McKinlay JB. Testosterone, sex hormone-binding globulin, and frailty in older men. J Am Geriatr Soc. 2007; 55:548-555.
53. Ensrud KE, Ewing SK, Fredman L, Hochberg MC, Cauley JA, Hillier TA, Cummings SR, Yaffe K, Cawthon PM, Study of Osteoporotic Fractures Research G. Circulating 25-hydroxyvitamin D levels and frailty status in older women. J Clin Endocrinol Metab. 2010; 95:5266-5273.
54. Yeap BB, Alfonso H, Chubb SA, Walsh JP, Hankey GJ, Almeida OP, Flicker L. Higher free thyroxine levels are associated with frailty in older men: The health in men study. Clin Endocrinol (Oxf). 2012; 76:741-748.
55. Shinall MC Jr, Arya S, Youk A, *et al.* Association of preoperative patient frailty and operative stress with postoperative mortality. JAMA Surg. 2020; 155:e194620.
56. Tang OY, Shao B, Kimata AR, Sastry RA, Wu J, Asaad WF. The impact of frailty on traumatic brain injury outcomes: An analysis of 691,821 nationwide cases. Neurosurgery. 2022; 91:808-820.
57. Shahrokni A, Alexander K. The age of talking about age

alone is over. Ann Surg Oncol. 2019; 26:12-14.
58. Dicpinigaitis AJ, Kazim SF, Schmidt MH, Couldwell WT, Theriault BC, Gandhi CD, Hanft S, Al-Mufti F, Bowers CA. Association of baseline frailty status and age with postoperative morbidity and mortality following intracranial meningioma resection. J Neurooncol. 2021; 155:45-52.
59. Theriault BC, Pazniokas J, Adkoli AS, Cho EK, Rao N, Schmidt M, Cole C, Gandhi C, Couldwell WT, Al-Mufti F, Bowers CA. Frailty predicts worse outcomes after intracranial meningioma surgery irrespective of existing prognostic factors. Neurosurg Focus. 2020; 49:E16.
60. Huq S, Khalafallah AM, Jimenez AE, Gami A, Lam S, Ruiz-Cardozo MA, Oliveira LAP, Mukherjee D. Predicting postoperative outcomes in brain tumor patients with a 5-factor modified frailty index. Neurosurgery. 2020; 88:147-154.
61. Shahrestani S, Lehrich BM, Tafreshi AR, Brown NJ, Lien BV, Ransom S, Ransom RC, Ballatori AM, Ton A, Chen XT, Sahyouni R. The role of frailty in geriatric cranial neurosurgery for primary central nervous system neoplasms. Neurosurg Focus. 2020; 49:E15.
62. Shahrokni A, Vishnevsky BM, Jang B, Sarraf S, Alexander K, Kim SJ, Downey R, Afonso A, Korc-Grodzicki B. Geriatric assessment, not ASA physical status, is associated with 6-month postoperative survival in patients with cancer aged ≥ 75 years. J Natl Compr Canc Netw. 2019; 17:687-694.
63. Rockwood K, Song X, MacKnight C, Bergman H, Hogan DB, McDowell I, Mitnitski A. A global clinical measure of fitness and frailty in elderly people. CMAJ. 2005; 173:489-495.
64. Gilbert T, Neuburger J, Kraindler J, Keeble E, Smith P, Ariti C, Arora S, Street A, Parker S, Roberts HC, Bardsley M, Conroy S. Development and validation of a hospital frailty risk score focusing on older people in acute care settings using electronic hospital records: An observational study. Lancet. 2018; 391:1775-1782.
65. Stuck AE, Siu AL, Wieland GD, Adams J, Rubenstein LZ. Comprehensive geriatric assessment: A meta-analysis of controlled trials. Lancet. 1993; 342:1032-1036.
66. Subramaniam S, Aalberg JJ, Soriano RP, Divino CM. New 5-factor modified frailty index using American college of surgeons NSQIP data. J Am Coll Surg. 2018; 226:173-181.e8.
67. Lakomkin N, Zuckerman SL, Stannard B, Montejo J, Sussman ES, Virojanapa J, Kuzmik G, Goz V, Hadjipanayis CG, Cheng JS. Preoperative risk stratification in spine tumor surgery: A comparison of the modified Charlson index, frailty index, and ASA score. Spine (Phila Pa 1976). 2019; 44:E782-E787.
68. Mijnarends DM, Schols JM, Meijers JM, Tan FE, Verlaan S, Luiking YC, Morley JE, Halfens RJ. Instruments to assess sarcopenia and physical frailty in older people living in a community (care) setting: Similarities and discrepancies. J Am Med Dir Assoc. 2015; 16:301-308.
69. Ferrando AA, Lane HW, Stuart CA, Davis-Street J, Wolfe RR. Prolonged bed rest decreases skeletal muscle and whole body protein synthesis. Am J Physiol. 1996; 270:E627-E633.
70. LeBlanc AD, Schneider VS, Evans HJ, Pientok C, Rowe R, Spector E. Regional changes in muscle mass following 17 weeks of bed rest. J Appl Physiol (1985). 1992; 73:2172-2178.
71. Paddon-Jones D, Sheffield-Moore M, Urban RJ, Sanford AP, Aarsland A, Wolfe RR, Ferrando AA. Essential amino acid and carbohydrate supplementation ameliorates muscle protein loss in humans during 28 days bedrest. J Clin Endocrinol Metab. 2004; 89:4351-4358.
72. Trappe TA, Burd NA, Louis ES, Lee GA, Trappe SW. Influence of concurrent exercise or nutrition countermeasures on thigh and calf muscle size and function during 60 days of bed rest in women. Acta Physiol (Oxf). 2007; 191:147-159.
73. Cruz-Jentoft AJ, Bahat G, Bauer J, *et al.* Sarcopenia: Revised European consensus on definition and diagnosis. Age aging. 2019; 48:16-31.
74. Tanaka T, Takahashi K, Hirano H, Kikutani T, Watanabe Y, Ohara Y, Furuya H, Tetsuo T, Akishita M, Iijima K. Oral frailty as a risk factor for physical frailty and mortality in community-dwelling elderly. J Gerontol A Biol Sci Med Sci. 2018; 73:1661-1667.
75. Lonergan B, Morgan C, Al-Raweshidy Y, Singh R. Choking as a cause of negative pressure pulmonary oedema (NPPE) in an older adult. Age aging. 2021; 50:592-594.
76. McHorney CA, Robbins J, Lomax K, Rosenbek JC, Chignell K, Kramer AE, Bricker DE. The SWAL-QOL and SWAL-CARE outcomes tool for oropharyngeal dysphagia in adults: III. Documentation of reliability and validity. Dysphagia. 2002; 17:97-114.
77. Belafsky PC, Mouadeb DA, Rees CJ, Pryor JC, Postma GN, Allen J, Leonard RJ. Validity and reliability of the Eating Assessment Tool (EAT-10). Ann Otol Rhinol Laryngol. 2008; 117:919-924.
78. Janssens JP, Pache JC, Nicod LP. Physiological changes in respiratory function associated with aging. Eur Respir J. 1999; 13:197-205.
79. Partridge JSL, Ryan J, Dhesi JK; CPOC-BGS perioperative frailty guideline group. New guidelines for the perioperative care of people living with frailty undergoing elective and emergency surgery-a commentary. Age aging. 2022; 51:afac237.
80. Perry R, Herbert G, Atkinson C, England C, Northstone K, Baos S, Brush T, Chong A, Ness A, Harris J, Haase A, Shah S, Pufulete M. Pre-admission interventions (prehabilitation) to improve outcome after major elective surgery: A systematic review and meta-analysis. BMJ Open. 2021; 11:e050806.
81. Mohamed B, Ramachandran R, Rabai F, Price CC, Polifka A, Hoh D, Seubert CN. Frailty assessment and prehabilitation before complex spine surgery in patients with degenerative spine disease: A narrative review. J Neurosurg Anesthesiol. 2023; 35:19-30.
82. Centre for Perioperative Care. Shared decision making for clinicians. *http://www.cpoc.org.uk/guidelines-resources-resources/shared-decision-making-clinicians* (accessed August 1, 2023)
83. Armstrong MJ. Shared decision-making in stroke: An evolving approach to improved patient care. Stroke Vasc Neurol. 2017; 2:84-87.
84. White S, Griffiths R, Baxter M, Beanland T, Cross J, Dhesi J, Docherty AB, Foo I, Jolly G, Jones J, Moppett IK, Plunkett E, Sachdev K. Guidelines for the peri-operative care of people with dementia: Guidelines from the Association of Anaesthetists. Anaesthesia. 2019; 74:357-372.
85. Chou R, Gordon DB, de Leon-Casasola OA, *et al.* Management of postoperative pain: A clinical practice guideline from the American pain society, the American

society of regional anesthesia and pain medicine, and the American society of anesthesiologists' committee on regional anesthesia, executive committee, and administrative council. J Pain. 2016; 17:131-157.
86. Griffiths R, Beech F, Brown A, Dhesi J, Foo I, Goodall J, Harrop-Griffiths W, Jameson J, Love N, Pappenheim K, White S, Association of Anesthetists of Great B, Ireland. Peri-operative care of the elderly 2014: Association of anaesthetists of Great Britain and Ireland. Anaesthesia. 2014; 69 Suppl 1:81-98.
87. Sprung CL, Artigas A, Kesecioglu J, *et al.* The Eldicus prospective, observational study of triage decision making in European intensive care units. Part II: Intensive care benefit for the elderly. Crit Care Med. 2012; 40:132-138.
88. Pearse RM, Harrison DA, James P, Watson D, Hinds C, Rhodes A, Grounds RM, Bennett ED. Identification and characterisation of the high-risk surgical population in the United Kingdom. Crit Care. 2006; 10:R81.
89. Centre for Perioperative Care. Guidance on establishing and delivering enhanced perioperative care services. *https://www.cpoc.org.uk/guidelines-resources-guidelines/enhanced-perioperative-care* (accessed August 1, 2023)
90. Killewich LA. Strategies to minimize postoperative deconditioning in elderly surgical patients. J Am Coll Surg. 2006; 203:735-745.
91. Marcantonio ER. Delirium in hospitalized older adults. N Engl J Med. 2017; 377:1456-1466.
92. Wang YY, Yue JR, Xie DM, Carter P, Li QL, Gartaganis SL, Chen J, Inouye SK. Effect of the tailored, family-involved hospital elder life program on postoperative delirium and function in older adults: A randomized clinical trial. JAMA Intern Med. 2020; 180:17-25.
93. Mudge AM, McRae P, Banks M, *et al.* Effect of a ward-based program on hospital-associated complications and length of stay for older inpatients: The cluster randomized CHERISH trial. JAMA Intern Med. 2022; 182:274-282.
94. Cederholm T, Jensen GL, Correia M, *et al.* GLIM criteria for the diagnosis of malnutrition - A consensus report from the global clinical nutrition community. J Cachexia Sarcopenia Muscle. 2019; 10:207-217.
95. Thibault R, Abbasoglu O, Ioannou E, Meija L, Ottens-Oussoren K, Pichard C, Rothenberg E, Rubin D, Siljamaki-Ojansuu U, Vaillant MF, Bischoff SC. ESPEN guideline on hospital nutrition. Clin Nutr. 2021; 40:5684-5709.
96. Fetterplace K, Deane AM, Tierney A, Beach LJ, Knight LD, Presneill J, Rechnitzer T, Forsyth A, Gill BMT, Mourtzakis M, MacIsaac C. Targeted full energy and protein delivery in critically ill patients: A pilot randomized controlled trial (FEED Trial). JPEN J Parenter Enteral Nutr. 2018; 42:1252-1262.

Received June 25, 2023; Revised August 16, 2023; Accepted August 22, 2023.

**Address correspondence to:*
Ying Xia, Department of Neurosurgery, Haikou Affiliated Hospital of Central South University Xiangya School of Medicine, No. 43 Renmin Avenue, Haidian Island, Haikou 570208, China.
E-mail: xiaying008@163.com

Peipei Song, Center for Clinical Sciences, National Center for Global Health and Medicine, 1-21-1 Toyama Shinjuku-ku, Tokyo 162-8655, Japan.
E-mail: psong@it.ncgm.go.jp

Released online in J-STAGE as advance publication August 25, 2023.