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ARTICLE

Does age or frailty have more predictive effect on outcomes following pedicled flap reconstruction? An analysis of 44,986 cases†

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ABSTRACT

The elderly population in the United States is expanding rapidly, and with advancements in modern medicine, the number of elderly patients undergoing surgery has risen in parallel. The aim of this study was to evaluate the effect of age and frailty on postoperative outcomes following pedicled flap reconstruction. The 2005–2016 ACS-NSQIP databases were queried to identify cases involving pedicled flaps based on CPT codes. Demographic data and postoperative complications were assessed using Chi-square and *t*-tests for analysis of categorical and continuous variables, respectively. A multivariable regression analysis was conducted to control for confounders. A total of 44,986 cases were included in our analysis. Patients in the 70–79year age group had the highest rates of all-cause (31.2%), mild systemic (25.3%) and severe systemic (7.4%) complications. Multivariable regression identified age as an independent risk factor for all-cause, severe systemic and wound complications. A score of 3+ on the 5-factor modified frailty index (mFI-5) was associated with all-cause, severe systemic and wound complications. When stratified by flap location, age was predictive of all-cause complications for breast, trunk, upper extremity and lower extremity flaps. Finally, mFI-5 score of 3+ was identified as an independent risk factor for all-cause complications in flaps of the head and neck, trunk and lower extremity. Although, increased age does contribute to risk of postoperative complications, the frailty index appears to hold much stronger predictive capacity. These findings stress the importance of optimizing preoperative comorbidities to reduce the risk of poor postoperative outcomes.

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Introduction

The United States is currently witnessing an unprecedented expansion of its elderly population [1]. According to the US Census Bureau, the number of individuals over the age of 65 is expected to increase 100% by 2050 [2]. In recent decades, advancements in anesthetic technique and postoperative care have enabled surgeons to operate successfully on patients over 80 years of age [3–6]. Given the increased incidence of malignancy and chronic wounds with old age [7,8], the number of patients requiring complex reconstructive surgeries is expected to increase accordingly [4]. Pedicled flaps are often an important component of such reconstructions. Furthermore, compared to microvascular free tissue transfer, pedicled flaps are generally considered to have a shorter operative time and hospital admission [9]. Despite these advantages, there is still considerable physiologic stress, and therefore, potential risk, associated with these flaps. Thus, there is strong need to assess the safety of these procedures in elderly patients.

Numerous prior studies have shown an increase in postoperative complications with advancing age [10–17]. In plastic surgery specifically, the majority of studies have focused on the safety of free tissue transfer in elderly patients, the results of which have been largely inconsistent [4,7,18–29]. Overall, there is a paucity of data regarding outcomes of elderly patients undergoing pedicled flap reconstruction in particular.

More recently, there has been increased interest in the concept of frailty, specifically as it relates to postoperative outcomes. Frailty refers to the deterioration of multiple physiologic systems that accumulates in an age-related fashion [30]. The Canadian Study of Health and Aging used 70 risk factors to develop a frailty index, which has been shown to predict adverse outcomes in surgical patients from numerous different specialties [31,32]. This model has been adapted for use in large national databases, such as the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) [33,34]. The most recent iteration, the 5-factor modified frailty index (mFI-5), is comprised of 5 ACS NSQIP variables pertaining to perioperative risk, and has been independently validated across multiple surgical specialties [33–35]. Interestingly, there is evidence that frailty may actually be a better predictor of postoperative morbidity and mortality when compared to chronologic age [32,36]. As such, we sought to examine the associated effect of increasing age and frailty on postoperative outcomes following pedicled flap reconstruction using the ACS NSQIP database.

Methods

Datasets

We conducted a retrospective analysis of the American College of Surgeons National Surgical Quality Improvement Program

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Description	CPT Code
Head and Neck	
Forehead flap with preservation of vascular pedicle (i.e., axial pattern v paramedian)	15731
Muscle, myocutaneous, or fasciocutaneous flap; head & neck	15732
Muscle flap for facial paralysis	15845
Excision of lip; transverse wedge excision, full thickness with local flap	40525
Excision of lip; transverse wedge excision, full thickness with cross lip flap	40527
Excision of lesion of tongue with local tongue flap	41114
Exenteration of orbit with muscle or myocutaneous flap	65114
Reconstruction of eyelid, full thickness by transfer of tarsoconjunctival flap from opposing eyelid; up to 2/3 of eyelid, 1 stage or first stage	67971
Total eyelid, lower, 1 stage or first stage	67973
Total eyelid, upper, 1 stage or first stage	67974
Breast	
Breast reconstruction with latissimus dorsi flap, without implant	19361
Breast reconstruction with TRAM, single pedicle	19367
TRAM with microvascular anastomosis (supercharged)	19368
Breast reconstruction with TRAM, double pedicle	19369
Trunk	
Direct or tubed pedicle; trunk	15570
Muscle, myocutaneous, or fasciocutaneous flap; trunk	15734
Omental flap, extra-abdominal (i.e., for reconstruction of sternal and chest wall defects)	49904
Upper extremity	
Muscle, myocutaneous, or fasciocutaneous flap; upper extremity	15736
Lower extremity	
Muscle, myocutaneous, or fasciocutaneous flap; lower extremity	15738
Excision, coccygeal pressure ulcer, with coccygectomy; with flap closure	15922
Excision, sacral pressure ulcer, with skin flap closure	15934
Excision, ischial pressure ulcer, with skin flap closure	15944
Excision, trochanteric pressure ulcer, with skin flap closure	15952

Figure 1. Current procedural terminology codes for pedicled flaps.

(ACS NSQIP) database from 2005 to 2016. The ACS NSQIP is a nationally validated, risk-adjusted, multi-institutional surgical outcomes program that collects data on approximately 240 variables, including demographics, preoperative co-morbidities and 30-day postoperative outcomes from over 400 institutions nationwide [37]. The data contained in this cohort is deidentified and available to all institutions adhering to the ACS NSQIP data use agreement. Methods of data collection have been previously described [38].

Cohort selection

Patients undergoing pedicled flap procedures were identified using Current Procedural Terminology (CPT) codes (Figure 1). Only those CPT codes that included information regarding the location of the pedicled flap were included to allow for stratification based on flap location. We also reviewed all other and concurrent CPT codes and excluded patients that underwent operations unrelated to the flap procedure. Flaps were categorized into head and neck, breast, trunk, upper extremity and lower extremity. For univariate analysis, subjects were divided into age groups 18–49, 50–59, 60–69, 70–79 and ≥80, consistent with prior ACS NSQIP studies [39]. Patients were excluded from the analysis if their age was not recorded.

Variables

We collected a number of variables pertaining to patient demographics, comorbidities and perioperative risk factors. These variables include baseline health characteristics, past medical and surgical history and American Society of Anesthesiologists physical status. A complete list of variables and corresponding definitions can be found on the National Surgical Quality Improvement Program website (http://site.acsnsqip.org/). Comorbidities were analyzed individually and subsequently combined to calculate a 5-factor modified frailty index (mFI-5) score, a composite measure consisting of five NSQIP variables, including functional status, diabetes, chronic obstructive pulmonary disease, congestive heart failure and hypertension [34].

Postoperative outcomes were collected and subjected to univariate analysis. We also defined several additional outcomes measures by aggregating variables pertaining to postoperative complications. Wound complications include superficial surgical-site infection (SSI), deep SSI, organ/space SSI and wound dehiscence. Mild systemic complications include pneumonia, bleeding requiring transfusion, DVT requiring therapy, sepsis, urinary tract infection, renal insufficiency and unplanned return to the operating room. Severe systemic complications include pulmonary embolism, unplanned intubation, ventilator support for greater than 48 h, renal failure requiring dialysis, cerebrovascular accident, cardiac arrest, myocardial infarction, septic shock and death within 30 days. Finally, all-cause complications represent all of the variables included in wound, mild systemic and severe systemic complications.

Statistical analysis

Univariate analysis was performed on demographics, comorbidities, perioperative risk factors and postoperative complications to assess for unadjusted differences between the five age cohorts. Pearson chi-square and *t*-tests were used to assess differences in categorical and continuous variables, respectively. Statistical significance was reported as $p < .05$. Variables with $p < .05$ on univariate analysis were included in a multivariable binary logistic regression with the composite adverse outcomes (all-cause complications, wound complications and severe systemic complications) as the dependent variable. All statistical analyses were performed using IBM SPSS version 24 for Windows (IBM Corp, Armonk, NY).

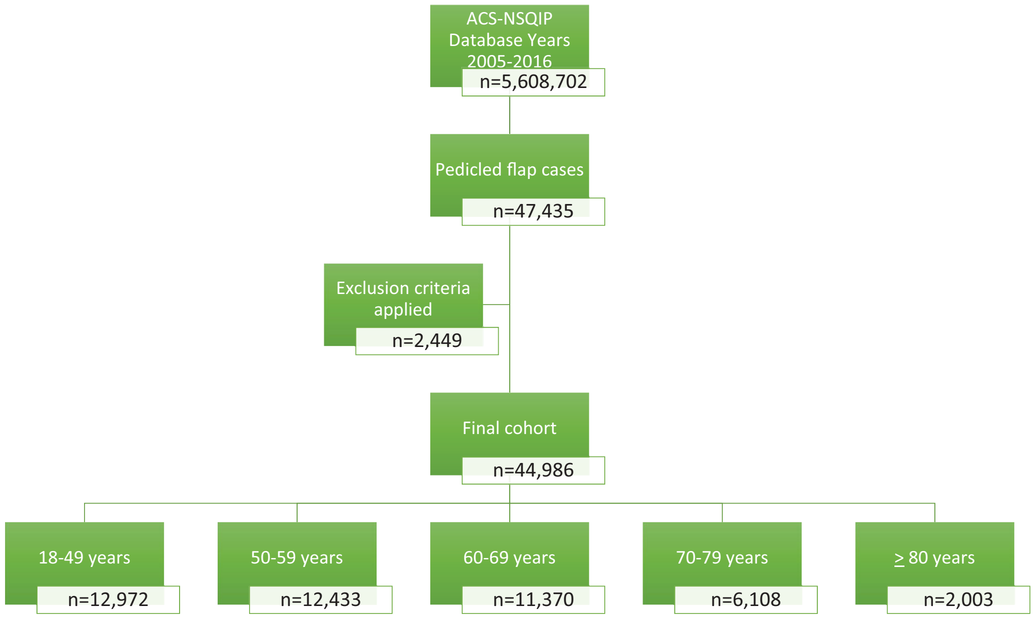

Figure 2. Data extraction strategy.

Results

Demographics and operative characteristics

A total of 47,435 initial cases of pedicled flaps were identified from the 5,608,702 cases contained within the ACS-NSQIP database from 2005 to 2016 (Figure 2). Predetermined exclusion criteria were then applied, which removed 2449 cases. The final study population consisted of 44,986 cases, of which, 4588 (10.2%) were head and neck, 8525 (19.0%) breast, 27,121 (60.3%) trunk, 591 (1.3%) upper extremity and 4161 (9.2%) lower extremity. The mean age for five (18–49, 50–59, 60–69, 70–79 and ≥80 years) cohorts was 40.2 ± 7.5, 54.6 ± 2.9, 64.3 ± 2.8, 73.7 ± 2.8 and 83.4 ± 2.6 years, respectively ($p < .001$), with an average age of 56.8 ± 13.6 years for the entire study population. From 2005 to 2016, the average age at the time of surgery has significantly increased ($p < .001$; Figure 3). Both head and neck as well as lower extremity flaps were progressively more frequent with increased age ($p < .001$). A more detailed summary of the demographic and operative information is located in Table 1.

Comorbidities

Significant differences between the five age cohorts were noted for all comorbidities (Table 2), with the exception of rates of preoperative radiotherapy. The average body mass index (BMI) for cohorts 1–3 (30.2 ± 8.2, 30.5 ± 7.8 and 30.2 ± 7.3 kg/m^2, respectively) met criteria for World Health Organization class I obesity (BMI 30.0–34.9 kg/m^2). The lowest average BMI was noted in the 80+ cohort (26.9 ± 5.4 kg/m^2). Both ASA classification ($p < .001$) and mFI-5 score ($p < .001$) trended upward with increased age. Rates of hypertension, cardiac disease and bleeding disorders were all noted to increase from cohorts 1 to 5 ($p < .001$, for all comparisons). Patients in the 80+ years cohort had the lowest rates of smoking (5.1%, $p < .001$) and the shortest operative times (186.5 ± 130.9 min, $p < .001$).

Complications

Rates of wound, mild systemic, severe systemic and all-cause complications were significantly different between the five cohorts ($p < .001$ for al; Table 3). Patients in cohort 4 (70–79 years) were noted to have the highest rates of all-cause (31.2% [$n = 1908$]), mild systemic (25.3% [$n = 1543$]) and severe systemic (7.4% [$n = 449$]) complications. Univariate analysis showed increased rates of death within 30 days, myocardial infarction and stroke with increased age ($p < .001$ for all three comparisons). Univariate analysis demonstrated a progressive increase in rates of all postoperative complications with increasing score on the mFI-5 scale ($p < .001$). Figure 4 summarizes this relationship between postoperative complication rates and mFI-5 score.

Multivariable regression analysis

To control for confounding variables, a multivariable regression analysis was performed for all-cause, severe systemic and wound complications (Table 4). Age was identified as an independent risk factor for all-cause (OR 1.015, 95% CI 1.013–1.017, $p < .001$), severe systemic (OR 1.045, 95% CI 1.040–1.049, $p < .001$) and wound (OR 1.003, 95% CI 1.000–1.005, $p = .032$) complications. A score of 3 or greater on the mFI-5 was also positively associated with all-cause (OR 2.616, 95% CI 2.293–2.984, $p < .001$), severe systemic (OR 3.114, 95% CI 2.599–3.731, $p < .001$) and wound (OR 1.362, 95% CI 1.153–1.609, $p < .001$) complications. Regression analysis for severe systemic and all-cause complications noted a stepwise increase in risk with additional mFI point (Figure 5).

When stratified by location of pedicled flap (Table 5), age was significantly associated with all-cause complications for breast (OR 1.010, 95% CI 1.004–1.006, $p = .002$), trunk (OR 1.014, 95% CI 1.012–1.016, $p < .001$), upper extremity (OR 1.015, 95% CI 1.001–1.030, $p = .041$) and lower extremity (OR 1.012, 95% CI 1.007–1.016, $p < .001$) flaps. Age was also associated with severe complications for breast (OR 1.043, 95% CI 1.019–1.068, $p < .001$), trunk (OR 1.045, 95% CI 1.040–1.050, $p < .001$) and lower extremity (OR 1.037, 95% CI 1.025–1.050, $p < .001$) flaps. Multivariable analysis for wound complications within each group of flaps showed no significant association with age.

A score of 3 or greater on the mFI-5 was predictive of all-cause complications for head and neck (OR 2.553, 95% CI 1.597–4.081, $p < .001$), trunk (OR 3.271, 95% CI 2.778–3.850, $p < .001$) and lower

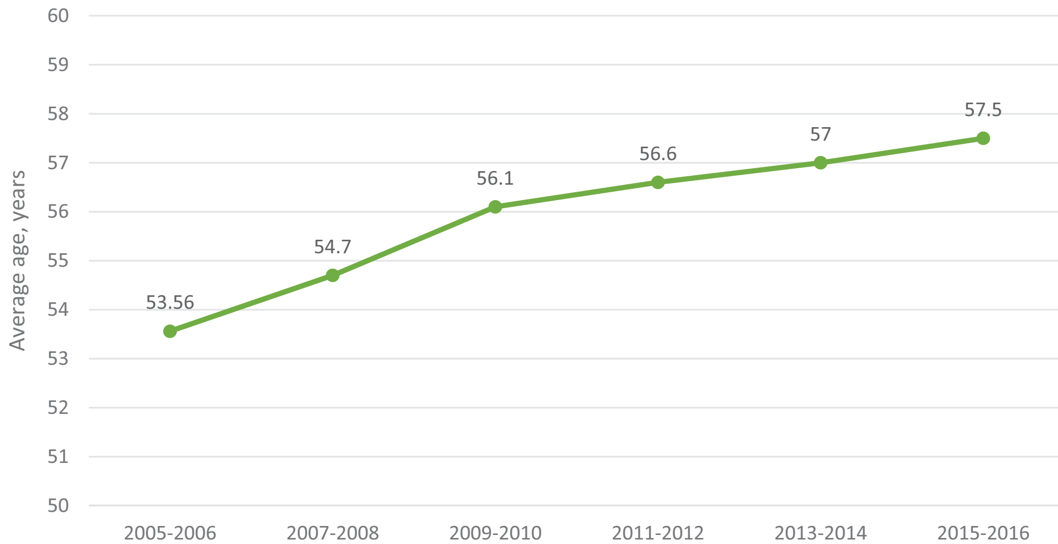

Figure 3. Average age at time of surgery by year.

Table 1. Demographics and reconstructive modality across all age groups.

	18–49 years	50–59 years	60–69 years	70–79 years	≥ 80 years	p
No. of patients	12,972	12,533	11,370	6108	2003	
Mean age ± SD, years	40.2±7.5	54.6±2.9	64.3±2.8	73.7±2.8	83.4±2.6	<.001
Female	8628 (66.5%)	7990 (63.8%)	6630 (58.3%)	3126 (51.2%)	994 (49.6%)	
Male	4339 (33.4%)	4536 (36.2%)	4735 (41.6%)	2974 (48.7%)	1008 (50.3%)	
Race						<.001
White	8948 (69.0%)	9311 (74.3%)	9028 (79.4%)	4975 (81.5%)	1677 (83.7%)	
Black	1613 (12.4%)	1298 (10.4%)	934 (8.2%)	380 (6.2%)	91 (4.5%)	
Asian	272 (2.1%)	158 (1.3%)	126 (1.1%)	65 (1.1%)	18 (0.9%)	
AI or AN	77 (0.6%)	53 (0.4%)	27 (0.2%)	8 (0.1%)	4 (0.2%)	
NH or PI	27 (0.2%)	19 (0.2%)	19 (0.2%)	3 (0.0%)	2 (0.1%)	
Unknown/Unreported	2035 (15.7%)	1694 (13.5%)	1236 (10.9%)	677 (11.1%)	211 (10.5%)	
Admission year						<.001
2016	2156 (16.6%)	2154 (17.2%)	2154 (18.9%)	1191 (19.5%)	383 (19.1%)	
2015	1928 (14.9%)	1967 (15.7%)	1963 (17.3%)	1048 (17.2%)	349 (17.4%)	
2014	1824 (14.1%)	1858 (14.8%)	1622 (14.3%)	897 (14.7%)	323 (16.1%)	
2013	1543 (11.9%)	1539 (12.3%)	1472 (12.9%)	788 (12.9%)	228 (11.4%)	
2012	1335 (10.3%)	1248 (10.0%)	1185 (10.4%)	623 (10.2%)	195 (9.7%)	
2011	1256 (9.7%)	1168 (9.3%)	1004 (8.8%)	555 (9.1%)	182 (9.1%)	
2010	840 (6.5%)	824 (6.6%)	698 (6.1%)	387 (6.3%)	137 (6.8%)	
2009	711 (5.5%)	598 (4.8%)	470 (4.1%)	244 (4.0%)	82 (4.1%)	
2008	599 (4.6%)	502 (4.0%)	380 (3.3%)	157 (2.6%)	66 (3.3%)	
2007	424 (3.3%)	372 (3.0%)	254 (2.2%)	126 (2.1%)	36 (1.8%)	
2005–2006	356 (2.7%)	303 (2.4%)	168 (1.5%)	92 (1.5%)	22 (1.1%)	
Surgical specialty						<.001
Cardiac	4 (0.0%)	6 (0.0%)	8 (0.1%)	8 (0.1%)	3 (0.1%)	
General surgery	7800 (60.1%)	7528 (60.1%)	6615 (58.2%)	3333 (54.6%)	841 (42.0%)	
Gynecology	63 (0.5%)	68 (0.5%)	61 (0.5%)	38 (0.6%)	17 (0.8%)	
Neurosurgery	167 (1.3%)	125 (1.0%)	152 (1.3%)	102 (1.7%)	23 (1.1%)	
Orthopedics	230 (1.8%)	201 (1.6%)	191 (1.7%)	109 (1.8%)	30 (1.5%)	
Otolaryngology	479 (3.7%)	711 (5.7%)	898 (7.9%)	665 (10.9%)	373 (18.6%)	
Plastics	3756 (29.0%)	3267 (26.1%)	2562 (22.5%)	1240 (20.3%)	502 (25.1%)	
Thoracic	237 (1.8%)	270 (2.2%)	336 (3.0%)	185 (3.0%)	32 (1.6%)	
Urology	87 (0.7%)	81 (0.6%)	127 (1.1%)	69 (1.1%)	23 (1.1%)	
Vascular	149 (1.1%)	276 (2.2%)	420 (3.7%)	359 (5.9%)	159 (7.9%)	
Flap type						<.001
Head & Neck	897 (6.9%)	939 (7.5%)	1189 (10.5%)	986 (16.1%)	577 (28.8%)	
Breast	3199 (24.7%)	3084 (24.6%)	1834 (16.1%)	377 (6.2%)	31 (1.5%)	
Trunk	7599 (58.6%)	7402 (59.1%)	7181 (63.2%)	3936 (64.4%)	1003 (50.1%)	
Upper extremity	222 (1.7%)	136 (1.1%)	109 (1.0%)	88 (1.4%)	36 (1.8%)	
Lower extremity	1055 (8.1%)	972 (7.8%)	1057 (9.3%)	721 (11.8%)	356 (17.8%)	

AI: American Indian; AN: Alaska Native; NH: Native Hawaiian; PI: Pacific Islander.

extremity (OR 2.754, 95% CI 2.105–3.603, $p < .001$) flaps. Additionally, mFI-5 score of 3 or greater was also associated with severe systemic complications for head and neck (OR 4.195, 95% CI 2.053–8.571, $p < .001$), trunk (OR 3.178, 95% CI 2.574–3.923, $p < .001$) and lower extremity (OR 4.034, 95% CI 2.724–5.974, $p < .001$) flaps. Finally, mFI-5 score of 3 or greater was predictive of wound complications for trunk flaps (OR 1.658, 95% CI 1.363–2.017, $p < .001$).

Table 2. Comorbidities and perioperative risk factors.

	18–49 years	50–59 years	60–69 years	70–79 years	**≥80 years**	*p*
No. of patients	12,972	12,533	11,370	6108	2003	
BMI, kg/m^2	30.2±8.2	30.5±7.8	30.2±7.3	29.1±6.6	26.9±5.4	**<.001**
5-Factor Modified Frailty Index						**<.001**
0 Points	9536 (73.5%)	6392 (51.0%)	3977 (35%)	1477 (24.2%)	376 (18.8%)	
1 Point	2663 (20.5%)	4292 (34.2%)	4823 (42.4%)	2904 (47.5%)	1068 (53.3%)	
2 Points	704 (5.4%)	1603 (12.8%)	2196 (19.3%)	1456 (23.8%)	440 (22.0%)	
3 Points	62 (0.5%)	224 (1.8%)	327 (2.9%)	236 (3.9%)	105 (5.2%)	
4 Points	5 (0.0%)	19 (0.2%)	41 (0.4%)	29 (0.5%)	14 (0.7%)	
5 Points	2 (0.0%)	3 (0.0%)	6 (0.1%)	6 (0.1%)	0 (0.0%)	
ASA Classification						**<.001**
ASA Class 1	1024 (7.9%)	315 (2.5%)	112 (1.0%)	32 (0.5%)	1 (0.0%)	
ASA Class 2	7184 (55.4%)	5716 (45.6%)	4087 (35.9%)	1559 (25.5%)	376 (18.8%)	
ASA Class 3	4459 (34.4%)	5960 (47.6%)	6450 (56.7%)	3929 (64.3%)	1356 (67.7%)	
ASA Class 4	280 (2.2%)	517 (4.1%)	689 (6.1%)	570 (9.3%)	249 (12.4%)	
ASA Class 5	2 (0.0%)	7 (0.1%)	6 (0.1%)	2 (0.0%)	6 (0.3%)	
Functional status[a]						**<.001**
Independent	12372 (95.4%)	12041 (96.1%)	10827 (95.2%)	5724 (93.7%)	1769 (88.3%)	
Partially dependent	383 (3.0%)	366 (2.9%)	402 (3.5%)	291 (4.8%)	169 (8.4%)	
Totally dependent	166 (1.3%)	97 (0.8%)	108 (0.9%)	74 (1.2%)	58 (2.9%)	
Smoking	3152 (24.3%)	3009 (24.0%)	2055 (18.1%)	742 (12.1%)	103 (5.1%)	**<.001**
Alcohol use	67 (0.5%)	101 (0.8%)	71 (0.6%)	41 (0.7%)	5 (0.2%)	.009
Hypertension	2566 (19.8%)	5213 (41.6%)	6625 (58.3%)	4252 (69.6%)	1502 (75.0%)	**<.001**
Diabetes	982 (7.6%)	1899 (15.2%)	2304 (20.3%)	1346 (22.0%)	369 (18.4%)	**<.001**
Cardiac disease	105 (0.8%)	250 (2.0%)	389 (3.4%)	360 (5.9%)	177 (8.8%)	**<.001**
Respiratory disease	642 (4.9%)	1333 (10.6%)	1627 (14.3%)	1114 (18.2%)	358 (17.9%)	**<.001**
Renal disease	104 (0.8%)	120 (1.0%)	135 (1.2%)	77 (1.3%)	26 (1.3%)	.050
Disseminated cancer	392 (3.0%)	516 (4.1%)	504 (4.4%)	277 (4.5%)	86 (4.3%)	**<.001**
Preop chemotherapy (within 30 days)	180 (1.4%)	161 (1.3%)	122 (1.1%)	47 (0.8%)	6 (0.3%)	**<.001**
Preop radiation (within 90 days)	80 (0.6%)	86 (0.7%)	86 (0.8%)	58 (0.9%)	12 (0.6%)	.121
Recent weight loss (>10% in 6 months)	204 (1.6%)	271 (2.2%)	296 (2.6%)	176 (2.9%)	55 (2.7%)	**<.001**
Prior operation within 30 days	204 (1.6%)	202 (1.6%)	183 (1.6%)	118 (1.9%)	67 (3.3%)	**<.001**
Current open wound	1558 (12.0%)	1439 (11.5%)	1511 (13.3%)	971 (15.9%)	435 (21.7%)	**<.001**
Steroid use	489 (3.8%)	480 (3.8%)	525 (4.6%)	298 (4.9%)	81 (4.0%)	**<.001**
Bleeding disorder	267 (2.1%)	417 (3.3%)	533 (4.7%)	432 (7.1%)	194 (9.7%)	**<.001**
Operative time, min	247.5 ±155.2	256.6±156.5	244.8±152.8	223.2 ±148.5	186.5±130.9	**<.001**
Length of stay, days	5.9±11.1	6.2±10.5	6.9±11.0	7.74±12.0	7.5±11.6	**<.001**

The statistical software used to perform these analyses generated '<0.001' where indicated. BMI: body mass index; ASA: American Society of Anesthesiologists; COPD: chronic obstructive pulmonary disease; CHF: congestive heart failure.
[a]Some variables had a smaller number of cases than the total population because of omitted data.

Table 3. Postoperative outcomes across all age groups.

	18–49 years	50–59 years	60–69 years	70–79 years	**≥80 years**	*p*
No. of patients	12,972	12,533	11,370	6108	2003	
All-cause complications[a]	2909 (22.4%)	3219 (25.7%)	3197 (28.1%)	1908 (31.2%)	593 (29.6%)	**<.001**
Wound complications[a]	1386 (10.7%)	1456 (11.6%)	1355 (11.9%)	662 (10.8%)	155 (7.7%)	**<.001**
Superficial SSI	613 (4.7%)	660 (5.3%)	581 (5.1%)	267 (4.4%)	77 (3.8%)	.007
Deep SSI	369 (2.8%)	370 (3.0%)	373 (3.3%)	165 (2.7%)	33 (1.6%)	.001
Organ/Space SSI	288 (2.2%)	292 (2.3%)	314 (2.8%)	172 (2.8%)	24 (1.2%)	**<.001**
Wound dehiscence	240 (1.9%)	286 (2.3%)	230 (2.0%)	136 (2.2%)	33 (1.6%)	.075
Mild systemic complications[a]	2156 (16.6%)	2430 (19.4%)	2449 (21.5%)	1543 (25.3%)	480 (24.0%)	**<.001**
Pneumonia	187 (1.4%)	278 (2.2%)	329 (2.9%)	270 (4.4%)	67 (3.3%)	**<.001**
Bleeding	879 (6.8%)	1125 (9.0%)	1219 (10.7%)	808 (13.2%)	248 (12.4%)	**<.001**
DVT Requiring therapy	110 (0.9%)	141 (1.1%)	136 (1.2%)	115 (1.8%)	23 (1.1%)	**<.001**
Sepsis	434 (3.3%)	432 (3.4%)	380 (3.3%)	226 (3.7%)	68 (3.4%)	.753
UTI	197 (1.5%)	205 (1.6%)	221 (1.9%)	148 (2.4%)	59 (2.9%)	**<.001**
Renal insufficiency	32 (0.2%)	50 (0.4%)	75 (0.7%)	48 (0.8%)	15 (0.7%)	**<.001**
Return to OR	952 (7.3%)	1043 (8.3%)	941 (8.3%)	527 (8.6%)	164 (8.2%)	**<.001**
Severe systemic complications[a]	241 (1.9%)	430 (3.4%)	572 (5.0%)	449 (7.4%)	142 (7.1%)	**<.001**
PE	70 (0.5%)	91 (0.7%)	109 (1.0%)	72 (1.2%)	21 (1.0%)	**<.001**
Unplanned intubation	106 (0.8%)	189 (1.5%)	273 (2.4%)	219 (3.6%)	46 (2.3%)	**<.001**
On ventilator >48 hours	167 (1.3%)	259 (2.1%)	316 (2.8%)	250 (4.1%)	53 (2.6%)	**<.001**
Renal failure	13 (0.1%)	44 (0.4%)	51 (0.4%)	46 (0.8%)	10 (0.5%)	**<.001**
Stroke/CVA	7 (0.1%)	16 (0.1%)	34 (0.3%)	21 (0.3%)	10 (0.5%)	**<.001**
Cardiac arrest	19 (0.1%)	36 (0.3%)	59 (0.5%)	61 (1.0%)	18 (0.9%)	**<.001**
Myocardial infarction	3 (0.0%)	41 (0.3%)	67 (0.6%)	62 (1.0%)	29 (1.4%)	**<.001**
Septic shock	73 (0.6%)	116 (0.9%)	169 (1.5%)	131 (2.1%)	38 (1.9%)	**<.001**
Death within 30 days	32 (0.2%)	64 (0.5%)	91 (0.8%)	120 (2.0%)	51 (2.5%)	**<.001**
Readmission	921 (7.1%)	927 (7.4%)	954 (8.4%)	509 (8.3%)	164 (8.2%)	.001
Length of stay >30 days	282 (2.2%)	254 (2.0%)	303 (2.7%)	217 (3.6%)	62 (3.1%)	**<.001**

The statistical software used to perform these analyses generated '<0.001' where indicated. SSI: surgical-site infection; DVT: deep vein thrombosis; UTI: urinary tract infection; OR: operating room; PE: pulmonary embolism; CVA: cerebrovascular accident.
[a]Aggregates of complications reflect the number of patients with at least one complication and thus this figure is not equal to the sum of the individual components.

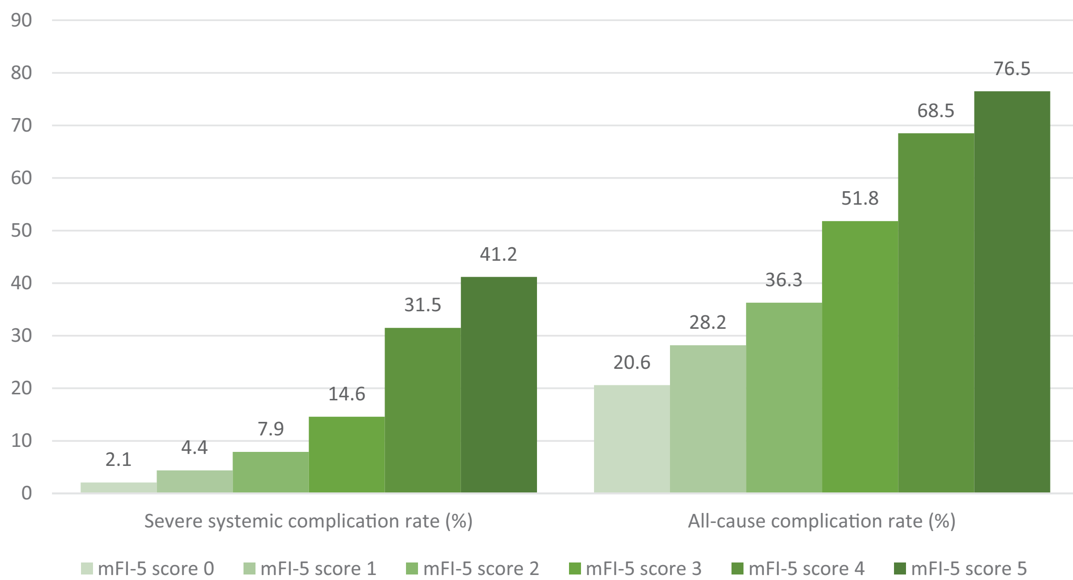

Figure 4. Relationship between mFI-5 score and rates of severe systemic (left) and all-cause (right) complications.

Table 4. Multivariable regression analysis of risk factors for postoperative complications.

	All-cause complications		Severe complications		Wound complications	
	OR (95% CI)	*p*	OR (95% CI)	*p*	OR (95% CI)	*p*
Age	1.015 (1.013–1.017)	<.001	1.045 (1.040–1.049)	<.001	1.003 (1.000–1.005)	.032
mFI-5 Score of 3+	2.616 (2.293–2.984)	<.001	3.114 (2.599–3.731)	<.001	1.362 (1.153–1.609)	<.001
Body Mass Index	1.020 (1.017–1.023)	<.001	1.034 (1.028–1.040)	<.001	1.036 (1.032–1.040)	<.001
Smoking	1.628 (1.542–1.719)	<.001	1.879 (1.677–2.098)	<.001	1.598 (1.490–1.714)	<.001
Steroid use	1.704 (1.537–1.889)	<.001	1.932 (1.605–2.327)	<.001	1.294 (1.126–1.487)	<.001
Preoperative wound infection	2.501 (2.349–2.662)	<.001	1.598 (1.411–1.810)	<.001	1.881 (1.736–2.038)	<.001
Operative time	1.004 (1.004–1.004)	<.001	1.002 (1.002–1.003)	<.001	1.002 (1.002–1.003)	<.001
Disseminated cancer	2.119 (1.910–2.351)	<.001	1.676 (1.387–2.024)	<.001	1.540 (1.153–1.756)	<.001

mFI-5: modified 5-factor frailty index.

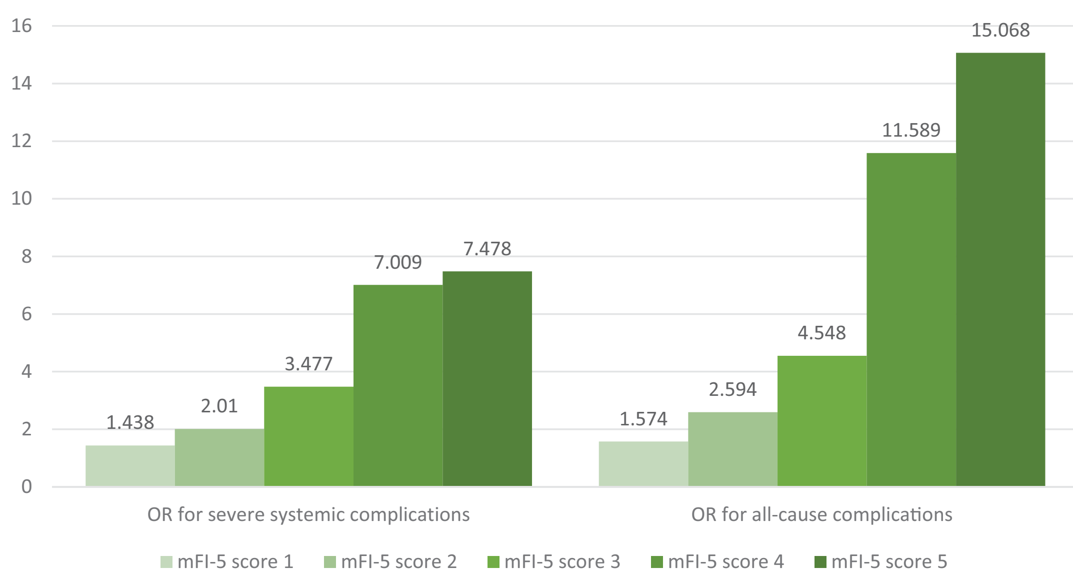

Figure 5. Adjusted odds ratio for mFI-5 score in multivariable regression analysis for severe systemic (left) and all-cause (right) complications.

Discussion

Advancements in healthcare have paralleled the increase in average life expectancy for individuals living in developed countries [40]. This notion is reinforced by the U.S. Census Bureau's suggestion that 'within just a couple decades, older people are projected to outnumber children for the first time in U.S. History' [41]. In surgery specifically, advanced age is thought to portend lower recovery potential and thus, increased risk for postoperative complications [10–17]. Furthermore, the process of aging is inherently associated with a progressive deterioration of physiologic capacity, a concept known as frailty [30]. Taken together, these findings have important implications for plastic surgeons, as a

Table 5. Multivariable regression analysis stratified by flap type.

	Age			mFI-5 Score of 3 or greater		
	OR	95% CI	*p*	OR	95% CI	*p*
All-cause complications						
Head & Neck	1.003	0.997–1.008	.378	2.553	1.597–4.081	**<.001**
Breast	1.010	1.004–1.016	**.002**	1.703	0.578–5.018	.334
Trunk	1.014	1.012–1.016	**<.001**	3.271	2.778–3.850	**<.001**
Upper extremity	1.015	1.001–1.030	**.041**	2.199	0.524–9.229	.282
Lower Extremity	1.012	1.007–1.016	**<.001**	2.754	2.105–3.603	**<.001**
Head & Neck	1.008	0.994–1.021	.257	4.195	2.053–8.571	**<.001**
Breast[b]	1.043	1.019–1.068	**<.001**		–	
Trunk	1.045	1.040–1.050	**<.001**	3.178	2.574–3.923	**<.001**
Upper Extremity[a]		–			–	
Lower Extremity	1.037	1.025–1.050	**<.001**	4.034	2.724–5.974	**<.001**
Wound complications						
Head & Neck	0.996	0.987–1.004	.306	1.667	0.833–3.335	.149
Breast	1.009	1.000–1.018	.053	1.196	0.265–5.408	.816
Trunk	1.001	0.998–1.004	.576	1.658	1.363–2.017	**<.001**
Upper extremity	0.984	0.963–1.005	.131	3.245	0.586–17.953	.177
Lower Extremity	1.000	0.994–1.007	.922	1.098	0.753–1.601	.627

The statistical software used to perform these analyses generated '<0.001' where indicated.

[a]Multivariable analysis was not performed for severe systemic complications in the upper extremity cohort because of the prohibitively low number of outcomes (6).

[b]Of the 75 severe systemic complications in the breast flap cohort, none had occurred in patients with mFI-5 score of 3 or greater.

substantial portion of reconstructive operations are performed in elderly patients, many of whom have significant comorbidities.

Overall, the results of our study indicate that an increase in age does indeed significantly impact surgical outcomes. Prior research on postoperative outcomes in elderly patients has identified similar trends across multiple surgical specialties [10–17]. In our study, patients between the ages of 70–79 had the highest rates of all-cause, mild systemic and severe systemic complications following pedicled flap reconstruction. Interestingly, the cohort of patients ≥80 years of age demonstrated a slightly lower rate of postoperative complications when compared to the 70- to 79-year-old cohort. This discrepancy can perhaps be explained by differences in perioperative risk noted between the two groups. Compared with patients aged 70–79 years, the 80+ year cohort had a lower rate of smoking, lower average BMI and shorter operative times. Multiple studies have found increased BMI and smoking to independently predict poor surgical outcomes [42–44]. Moreover, patient selection may play a role. With a patient over 80 years, a surgeon may be more reluctant to perform complex reconstructive surgery given the relatively greater risk of morbidity and mortality. As such, surgeons may choose to operate on patients who are optimized for surgery. This is supported by Tan et al who recommend a collaborative, multidisciplinary approach for optimal management of the elderly surgical patient [45].

Increased age was noted to be an independent predictor for wound complications in our study. This finding is consistent with the current literature, which demonstrates an increased incidence of superficial surgical site infection (SSI) with increased age [46]. Kaye et al found that, although, increasing age served as a predictor for SSI, this was only true up to the age of 65 [47]. Similarly, in our study, the rate of wound complications decreased from 11.9% to 10.8%, and finally 7.7% for patients ages 60–69, 70–79 and ≥80 years, respectively. Kaye et al attributed this phenomenon to the 'hardy survivor effect' where it is implied that persons who survive to older ages may have a better working immune system [46,47].

Prior research on postoperative outcomes following reconstructive surgery in the elderly has yielded inconsistent results [4,7,18,26–29,48]. Multiple studies have demonstrated the safety of free tissue transfer in the elderly, noting that age was not independently associated with poor postoperative outcomes [21–23,25,28]. However, numerous authors have observed higher rates of medical complications in elderly patients undergoing free flap reconstruction, even after controlling for comorbid conditions [4,18,19]. Although, the results of our multivariable regression model identified age as an independent risk factor for all-cause, severe systemic and wound complications, the predictive power was not overwhelmingly strong. As such, the clinical relevance of chronological age alone may not be considerable enough to modify patient management. Given the importance of risk stratification in perioperative decision making, we sought to evaluate the impact of frailty on outcomes following pedicled flap using the 5-factor modified frailty index (mFI-5) [34]. Frailty is defined as a condition in which there is a significantly higher risk for developing dependency, morbidity or mortality after being exposed to a stressor, such as a surgical intervention [30,49]. Recent literature shows that the frailty indices, such as the mFI-5, may be a more powerful predictor of postoperative outcomes when compared to chronological age [50–52]. Indeed, our results echo many of these findings, with frailty index demonstrating a significantly stronger predictive capacity when compared to chronological age alone. Furthermore, our data suggest an additive, rather than linear, relationship between frailty index score and risk of postoperative complications. Figures 4 and 5 highlight the near exponential rise in unadjusted and adjusted risk, respectively.

In our study, an mFI score of 3 or greater was associated with a more than twofold increase in risk for developing complications of any cause, and a more than threefold increase in risk for developing severe systemic complications. In comparison, one additional year of age was noted to portend only a 0.15% increase in risk for all-cause and 0.45% increase in risk for severe systemic complications. These findings are consistent with recent studies that highlight the predictive capacity of the mFI score [53–55]. Similar to our results, both Farhat et al. [53] and Tsiouris et al. [55] noted the difference in adjusted risk for postoperative complications between increased age and mFI score, with the latter showing significantly higher predictive potential.

Differences in adjusted risk for age and mFI score were noted when cases were stratified by flap location. Specifically, mFI sore of 3 or greater was positively associated with all-cause (OR 2.553) and severe systemic (OR 4.195) complications in the head and neck, while age showed no relationship. This is consistent with a 2016 systematic review of head and neck free flaps in the elderly, which noted that preoperative comorbidity, as measured by three comorbidity indices (Kaplan-Feinstein, Adult Comorbidity Evaluation and Index of Coexistent Diseases score), was independently predictive of postoperative complications, while chronological age alone was not [24]. Goh et al. also found preoperative comorbidity, and not chronological age, to be independently associated with complications following head and neck reconstruction [23].

Complications following pedicled trunk flaps were predicted by both age and mFI score in our study, albeit with a stronger association for mFI score. Calotta et al reported outcomes of posterior trunk reconstruction using paraspinal and other flaps in elderly patients and found only ASA score to be independently predictive of postoperative complications [21]. Ozkan [27], Howard [4] and Sierakowski [29] have published their experiences with elderly patients undergoing free tissue transfer for head and neck, breast, upper and lower extremity and trunk reconstruction. All of these studies identified preoperative comorbidities, and not chronological age, to be independently associated with postoperative complications. In comparison, our analysis found that both age and mFI score were independently associated with severe systemic complications for upper and lower extremity flaps. Interestingly, we also found that age was predictive of all-cause and severe systemic complications in breast flaps, while mFI score was not.

Overall, this study reinforces a number of important principles regarding preoperative patient evaluation. While chronological age does appear to impart additional risk for postoperative complications, the extent to which age alone should impact decision making is unclear. Importantly, the predictive power, and therefore, the clinical relevance, of a composite measure such as frailty should be recognized and integrated along with chronological age in preoperative assessment and planning.

Although, the ACS NSQIP database allows for a robust evaluation of multi-institutional data, there are several limitations, many of which have been previously described [56,57]. Specifically, case identification relies on CPT and/or ICD coding. Therefore, the rigorousness with which these procedures/diagnoses are defined and coded inherently determines the degree of granularity present in the study. Additionally, studies using the ACS NSQIP database are bound by the variables available in the dataset, and therefore, aesthetic and patient-reported outcomes were not included in this study. Furthermore, postoperative outcomes data are only collected for 30 days, thereby precluding an evaluation of potential long-term complications. Other limitations include potential for inaccurate data entry and intra- and inter-institutional variations in reporting practices. Also, it is important to note that the number and composition of institutions enrolled in the ACS NSQIP frequently changes from year-to-year. Thus, trend analyses may be subject to bias, and in the absence of statistical weighting of the dataset, results generated from this database should not be extrapolated onto a population level. Finally, pedicled flaps in different regions of the body may also vary in complexity as well as the patient population in which they are commonly performed. As such, interpretation of statistical results using data from all flaps should bear this in mind. However, the large sample size and additional stratified statistical analyses for flap location can help to buffer against such confounding.

Notwithstanding these limitations, this study provides valuable information regarding the impact of age and frailty on postoperative complications following pedicled flap reconstructive surgery. Further studies are necessary in order to address the financial, functional and psychosocial impact of pedicled flap reconstruction in this population.

Conclusions

The results of this study show that increased age and frailty are independently associated with an increased risk of postoperative complications following pedicled flap reconstruction. Although, age alone had statistically significant predictive capabilities, the mFI-5 appears to be a better measure of postoperative complication risk. The mFI can be adjusted to many existing datasets and applied clinically, thus, making it a versatile and reliable analytical index score to be used for risk stratification prior to pedicled flap surgery.

Ethical approval

The patient information in this study is de-identified and available to all institutions complying with the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) Data Use Agreement.

Disclosure statement

The ACS NSQIP databases are the source of information used in this study. Data extrapolated, statistical analysis performed and conclusions reached have not been verified by the ACS NSQIP but rather are the result of the work done by the authors of this study.

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References

[1] Vincent GK, Velkoff VA. The next four decades: the older population in the United States: 2010 to 2050: US Department of Commerce, Economics and Statistics Administration. Maryland: US Census Bureau; 2010.
[2] Hobbs F, Damon BL. Sixty-five plus in the United States. Maryland: US Department of Commerce, Bureau of the Census; 1996.
[3] Karakoc D. Surgery of the elderly patient. Int Surg. 2016; 101(3–4):161–166.
[4] Howard MA, Cordeiro PG, Disa J, et al. Free tissue transfer in the elderly: incidence of perioperative complications following microsurgical reconstruction of 197 septuagenarians and octogenarians. Plast Reconstr Surg. 2005;116(6): 1659–1668.
[5] Hamel MB, Henderson WG, Khuri SF, et al. Surgical outcomes for patients aged 80 and older: morbidity and mortality from major noncardiac surgery. J Am Geriatr Soc. 2005;53(3):424–429.
[6] Turrentine FE, Wang H, Simpson VB, et al. Surgical risk factors, morbidity, and mortality in elderly patients. J Am Coll Surg. 2006;203(6):865–877.
[7] Grammatica A, Piazza C, Paderno A, et al. Free flaps in head and neck reconstruction after oncologic surgery: expected outcomes in the elderly. Otolaryngol Head Neck Surg. 2015;152(5):796–802.
[8] Rasero L, Simonetti M, Falciani F, et al. Pressure ulcers in older adults: a prevalence study. Adv Skin Wound Care. 2015;28(10):461–464.
[9] Fang Z, Tian Z, Zhang C, et al. Risk factors for pedicle flap complications in 251 elderly Chinese patients who underwent oral and maxillofacial reconstruction. J Oral Maxillofac Surg. 2016;74(10):2073–2080.
[10] Dhesi J. Improving outcomes in older people undergoing elective surgery. JRCPE. 2010;40(4):348–353.
[11] Massarweh NN, Legner VJ, Symons RG, et al. Impact of advancing age on abdominal surgical outcomes. Arch Surg. 2009;144(12):1108–1114.
[12] Polanczyk CA, Marcantonio E, Goldman L, et al. Impact of age on perioperative complications and length of stay in patients undergoing noncardiac surgery. Ann Intern Med. 2001;134(8):637–643.
[13] Weintraub WS, Craver JM, Cohen CL, et al. Influence of age on results of coronary artery surgery. Circulation. 1991;84(5 Suppl):III226–III235.
[14] Goldman L, Caldera DL, Nussbaum SR, et al. Multifactorial index of cardiac risk in noncardiac surgical procedures. N Engl J Med. 1977;297(16):845–850.
[15] Hanover N. Operative mortality with elective surgery in older adults. Eff Clin Pract. 2001;4(4):172–177.

[16] Liu LL, Leung JM. Predicting adverse postoperative outcomes in patients aged 80 years or older. J Am Geriatr Soc. 2000;48(4):405–412.
[17] Mistry PK, Gaunay GS, Hoenig DM. Prediction of surgical complications in the elderly: can we improve outcomes? Asian J Urol. 2017;4(1):44–49.
[18] Beausang ES, Ang EE, Lipa JE, et al. Microvascular free tissue transfer in elderly patients: the Toronto experience. Head Neck. 2003;25(7):549–553.
[19] Blackwell KE, Azizzadeh B, Ayala C, et al. Octogenarian free flap reconstruction: complications and cost of therapy. Otolaryngol Head Neck Surg. 2002;126(3):301–306.
[20] Bridger AG, O'Brien CJ, Lee KK. Advanced patient age should not preclude the use of free-flap reconstruction for head and neck cancer. Am J Surg. 1994;168(5):425–428.
[21] Calotta NA, Coon D, Sacks JM. Safety of immediate posterior trunk soft-tissue reconstruction in older adults. Plast Reconstr Surg Glob Open. 2017;5(5):e1326.
[22] Coskunfirat OK, Chen HC, Spanio S, et al. The safety of microvascular free tissue transfer in the elderly population. Plast Reconstr Surg. 2005;115(3):771–775.
[23] Goh CS, Kok YO, Yong CP, et al. Outcome predictors in elderly head and neck free flap reconstruction: a retrospective study and systematic review of the current evidence. J Plast Reconstr Aesthet Surg. 2018;71(5):719–728.
[24] Hwang K, Lee JP, Yoo SY, et al. Relationships of comorbidities and old age with postoperative complications of head and neck free flaps: a review. J Plast Reconstr Aesthet Surg. 2016;69(12):1627–1635.
[25] Kwok AC, Agarwal JP. Unplanned reoperations after microvascular free tissue transfer: an analysis of 2,244 patients using the american college of surgeons national surgical quality improvement program database. Microsurgery. 2017;37(3):184–189.
[26] Malata CM, Cooter RD, Batchelor AG, et al. Microvascular free-tissue transfers in elderly patients: the leeds experience. Plast Reconstr Surg. 1996;98(7):1234–1241.
[27] Ozkan O, Ozgentas HE, Islamoglu K, et al. Experiences with microsurgical tissue transfers in elderly patients. Microsurgery. 2005;25(5):390–395.
[28] Serletti JM, Higgins JP, Moran S, et al. Factors affecting outcome in free-tissue transfer in the elderly. Plast Reconstr Surg. 2000;106(1):66–70.
[29] Sierakowski A, Nawar A, Parker M, et al. Free flap surgery in the elderly: experience with 110 cases aged $\geq$ 70 years. J Plast Reconstr Aesthet Surg. 2017;70(2):189–195.
[30] Lin HS, Watts JN, Peel NM, et al. Frailty and post-operative outcomes in older surgical patients: a systematic review. BMC Geriatr. 2016;16(1):157.
[31] Searle SD, Mitnitski A, Gahbauer EA, et al. A standard procedure for creating a frailty index. BMC Geriatr. 2008;8(1):24.
[32] Rockwood K, Howlett SE, MacKnight C, et al. Prevalence, attributes, and outcomes of fitness and frailty in community-dwelling older adults: report from the Canadian study of health and aging. J Gerontol A Biol Sci Med Sci. 2004; 59(12):1310–1317.
[33] Velanovich V, Antoine H, Swartz A, et al. Accumulating deficits model of frailty and postoperative mortality and morbidity: its application to a national database. J Surg Res. 2013;183(1):104–110.
[34] Subramaniam S, Aalberg JJ, Soriano RP, et al. New 5-factor modified frailty index using American college of surgeons NSQIP data. J Am Coll Surg. 2018;226(2):173–181 e8.
[35] Traven SA, Reeves RA, Althoff AD, et al. New five-factor modified frailty index predicts morbidity and mortality in geriatric hip fractures. J Orthop Trauma. 2019;33(7):319–323.
[36] Song X, Mitnitski A, Rockwood K. Prevalence and 10-year outcomes of frailty in older adults in relation to deficit accumulation. J Am Geriatr Soc. 2010;58(4):681–687.
[37] Nsqip A. User guide for the 2012 ACS NSQIP participant use data file. Accessed Feb 24. 2019. Available at: https://www.facs.org/-/media/files/quality-programs/nsqip/ug12.ashx.
[38] Birkmeyer JD, Shahian DM, Dimick JB, et al. Blueprint for a new American college of surgeons: national surgical quality improvement program. J Am Coll Surg. 2008;207(5):777–782.
[39] Jubbal KT, Zavlin D, Suliman A. The effect of age on microsurgical free flap outcomes: an analysis of 5,951 cases. Microsurgery. 2017;37(8):858–864.
[40] Christensen K, Doblhammer G, Rau R, et al. Ageing populations: the challenges ahead. Lancet. 2009;374(9696): 1196–1208.
[41] The United States Census Bureau. Older People Projected to Outnumber Children [Internet]; [cited Feb 24, 2019]. Available from: https://www.census.gov/newsroom/press-releases/2018/cb18-41-population-projections.html
[42] Theadom A, Cropley M. Effects of preoperative smoking cessation on the incidence and risk of intraoperative and postoperative complications in adult smokers: a systematic review. Tob Control. 2006;15(5):352–358.
[43] Gao M, Sun J, Young N, et al. Impact of body mass index on outcomes in cardiac surgery. J Cardiothorac Vasc Anesth. 2016;30(5):1308–1316.
[44] Ri M, Miyata H, Aikou S, et al. Effects of body mass index (BMI) on surgical outcomes: a nationwide survey using a Japanese web-based database. Surg Today. 2015;45(10): 1271–1279.
[45] Tan KY, Konishi F, Tan L, et al. Optimizing the management of elderly colorectal surgery patients. Surg Today. 2010; 40(11):999–1010.
[46] Kaye KS, Anderson DJ, Sloane R, et al. The effect of surgical site infection on older operative patients. J Am Geriatr Soc. 2009;57(1):46–54.
[47] Kaye KS, Schmit K, Pieper C, et al. The effect of increasing age on the risk of surgical site infection. J Infect Dis. 2005; 191(7):1056–1062.
[48] Bridger AG, O'Brien CJ, Lee KK. Advanced patient age should not preclude the use of free-flap reconstruction for head and neck cancer. Am J Surg. 1994;168(5):425–428.
[49] Morley JE, Vellas B, van Kan GA, et al. Frailty consensus: a call to action. J Am Med Dir Assoc. 2013;14(6):392–397.
[50] Ali TZ, Lehman EB, Aziz F. Modified frailty index can be used to predict adverse outcomes and mortality after lower extremity bypass surgery. Ann Vasc Surg. 2018;46:168–177.
[51] Uppal S, Igwe E, Rice LW, et al. Frailty index predicts severe complications in gynecologic oncology patients. Gynecol Oncol. 2015;137(1):98–101.
[52] Wachal B, Johnson M, Burchell A, et al. Association of modified frailty index score with perioperative risk for patients undergoing total laryngectomy. JAMA Otolaryngol Head Neck Surg. 2017;143(8):818–823.
[53] Farhat JS, Velanovich V, Falvo AJ, et al. Are the frail destined to fail? Frailty index as predictor of surgical morbidity and mortality in the elderly. J Trauma Acute Care Surg. 2012;72(6):1526–1530.

[54] Weaver DJ, Malik AT, Jain N, et al. The modified 5-item frailty index: a concise and useful tool for assessing the impact of frailty on postoperative morbidity following elective posterior lumbar fusions. World Neurosurg. 2019.
[55] Tsiouris A, Hammoud ZT, Velanovich V, et al. A modified frailty index to assess morbidity and mortality after lobectomy. J Surg Res. 2013;183(1):40–46.
[56] Shah R, Velanovich V, Syed Z, et al. Limitations of patient-associated co-morbidity model in predicting postoperative morbidity and mortality in pancreatic operations. J Gastrointest Surg. 2012;16(5):986–992.
[57] Epelboym I, Gawlas I, Lee JA, et al. Limitations of ACS-NSQIP in reporting complications for patients undergoing pancreatectomy: underscoring the need for a pancreas-specific module. World J Surg. 2014;38(6):1461–1467.