JAMA Facial Plastic Surgery | Original Investigation

Association of Anesthesia Duration With Complications After Microvascular Reconstruction of the Head and Neck

Jacob S. Brady, BA; Stuti V. Desai, BA; Meghan M. Crippen, MS; Jean Anderson Eloy, MD; Yuriy Gubenko, MD; Soly Baredes, MD; Richard Chan Woo Park, MD

IMPORTANCE Prolonged anesthesia and operative times have deleterious effects on surgical outcomes in a variety of procedures. However, data regarding the influence of anesthesia duration on microvascular reconstruction of the head and neck are lacking.

OBJECTIVE To examine the association of anesthesia duration with complications after microvascular reconstruction of the head and neck.

DESIGN, SETTING, AND PARTICIPANTS The American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database was used to collect data. In total, 630 patients who underwent head and neck microvascular reconstruction were recorded in the NSQIP registry from January 1, 2005, through December 31, 2013. Patients who underwent microvascular reconstructive surgery performed by otolaryngologists or plastic surgeons were included in this study. Data analysis was performed from October 15, 2015, to January 15, 2016.

EXPOSURES Microvascular reconstructive surgery of the head and neck.

MAIN OUTCOMES AND MEASURES Patients were stratified into 5 quintiles based on mean anesthesia duration and analyzed for patient characteristics and operative variables (mean [SD] anesthesia time: group 1, 358.1 [175.6] minutes; group 2, 563.2 [27.3] minutes; group 3, 648.9 [24.0] minutes; group 4, 736.5 [26.3] minutes; and group 5, 922.1 [128.1] minutes). Main outcomes include rates of postoperative medical and surgical complications and mortality.

RESULTS A total of 630 patients undergoing head and neck free flap surgery had available data on anesthesia duration and were included (mean [SD] age, 61.6 [13.8] years; 436 [69.3%] male). Bivariate analysis revealed that increasing anesthesia duration was associated with increased 30-day complications overall (55 [43.7%] in group 1 vs 80 [63.5%] in group 5, $P = .006$), increased 30-day postoperative surgical complications overall (45 [35.7%] in group 1 vs 78 [61.9%] in group 5, $P < .001$), increased rates of postoperative transfusion (32 [25.4%] in group 1 vs 70 [55.6%] in group 5, $P < .001$), and increased rates of wound disruption (0 in group 1 vs 10 [7.9%] in group 5, $P = .02$). No specific medical complications and no overall medical complication rate (24 [19.0%] in group 1 vs 22 [17.5%] in group 5, $P = .80$) or mortality (1 [0.8%] in group 1 vs 1 [0.8%] in group 5, $P = .75$) were associated with increased anesthesia duration. On multivariate analysis accounting for demographics and significant preoperative factors including free flap type, overall complications (group 5: odds ratio [OR], 1.98; 95% CI, 1.10-3.58; $P = .02$), surgical complications (group 5: OR, 2.46; 95% CI, 1.35-4.46; $P = .003$), and postoperative transfusion (group 5: OR, 2.31; 95% CI, 1.27-4.20; $P = .006$) remained significantly associated with increased anesthesia duration; the association of wound disruption and increased anasthesia duration was nonsignificant (group 5: OR, 2.0; 95% CI, 0.75-5.31; $P = .16$).

CONCLUSIONS AND RELEVANCE Increasing anesthesia duration was associated with significantly increased rates of surgical complications, especially the requirement for postoperative transfusion. Rates of medical complications were not significantly altered, and overall mortality remained unaffected. Avoidance of excessive blood loss and prolonged anesthesia time should be the goal when performing head and neck free flap surgery.

JAMA Facial Plast Surg. doi:10.1001/jamafacial.2017.1607
Published online October 5, 2017.
LEVEL OF EVIDENCE 3.

Supplemental content

Author Affiliations: Department of Otolaryngology–Head and Neck Surgery, Rutgers New Jersey Medical School, Newark (Brady, Desai, Crippen, Eloy, Baredes, Park); Center for Skull Base and Pituitary Surgery, Neurological Institute of New Jersey, Rutgers New Jersey Medical School, Newark (Eloy, Baredes); Department of Neurological Surgery, Rutgers New Jersey Medical School, Newark (Eloy); Department of Ophthalmology, Rutgers New Jersey Medical School, Newark (Eloy); Department of Anesthesiology, Rutgers New Jersey Medical School, Newark (Gubenko).

Corresponding Author: Richard Chan Woo Park, MD, Department of Otolaryngology–Head and Neck Surgery, Rutgers New Jersey Medical School, 90 Bergen St, Ste 8100, Newark, NJ 07103 (cwp39@njms.rutgers.edu).

Free tissue transfer is widely regarded as the criterion standard for reconstruction in the surgical management of head and neck cancers, facilitating optimal functional and aesthetic outcomes. Since its introduction, microvascular technology and technique have undergone developments that have made free flap repairs safe and effective, with a success rate of 91% to 99%.[1-3] However, patients are still subject to postoperative complications that result from the complex nature of the procedure, long operative course, and suboptimal preoperative health status. These complications may contribute to the rare flap failure, which is associated with substantial morbidity and significant cost to the patient and health care system.[4-6]

The frequency and potential severity of complications after free flap repairs of the head and neck necessitate a thorough investigation of outcome predictors. Although several studies[3,5-9] have sought to identify risk factors associated with flap failure, results among various institutional analyses conflict, and generalizable data are lacking.[2,10] One variable in particular requiring additional investigation is anesthesia duration for which, to our knowledge, there is no analysis of population-based data specific to patients undergoing head and neck surgery. The association between increased operative time and morbidity has been well documented in general and procedure-specific analyses.[11-14] Several studies[11,12,14] have found that a longer operation is associated with increased rates of infection, wound disruption, and thrombotic events in patients undergoing free flap surgery. In addition, prolonged anesthesia duration may be particularly important in microvascular surgery because flap viability is intimately related to the degree of intraoperative hemodynamic control.[15]

The need for this analysis was further evidenced by the varied anesthetic management of patients undergoing free flap surgery, suggesting a paucity of data with which to construct evidence-based guidelines.[16,17] Anesthesia duration represents a modifiable risk factor, and the identification of significant associations may help guide patient selection and intraoperative decision making. This study aimed to elucidate possible associations between anesthesia duration, preoperative characteristics, and postoperative complications in patients undergoing head and neck free flap surgery by using population-based data collected from the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database.

Key Points

Questions Does increased anesthesia duration increase rates of specific postoperative complications in free flap reconstruction of the head and neck?

Findings In this study of 630 patients who underwent head and neck free flap procedures, those who were obese, had an osseous free flap, or had multiple free flaps were found to have longer anesthesia duration. After confounding factors were accounted for, increased anesthesia duration was associated with increased rates of overall postoperative complications, surgical complications, and transfusions.

Meaning Increasing anesthesia duration was associated with significantly increased rates of surgical complications, especially the requirement for postoperative transfusion; therefore, avoidance of excessive blood loss and prolonged anesthesia time should be the goal of the reconstructive surgeon when performing head and neck free flap surgery.

Methods

A retrospective analysis was performed on data from the NSQIP participant use files for January 1, 2005, through December 31, 2013. The NSQIP database was accessed in October 2015 to identify patients who underwent free flap reconstruction of the head and neck between 2005 and 2013 using the *Current Procedural Terminology* codes outlined in the eTable in the Supplement. Data analysis was performed from October 15, 2015, to January 15, 2016. Patients who underwent a free flap and concurrent head and neck cancer procedures were included in the final cohort. Only patients with information regarding anesthesia duration were included in the analysis. In addition, patients with an anesthesia duration of 0 minutes were excluded from the analysis under the assumption that this was a coding error or aborted procedure. This analysis was determined to be exempt from approval by the Rutgers New Jersey Medical School Institutional Review Board because of the deidentified format of the NSQIP data set; therefore, no patient informed consent was required.

Patients were subsequently stratified into 5 ranked quintiles based on duration of anesthesia to more precisely capture the specific anesthesia durations that may be associated with a particular complication. Patients with tied duration were grouped in the same quintile, resulting in small variations in quintile population sizes. Preoperative patient characteristics and operative variables are given in **Table 1** and **Table 2**, respectively. Comorbidities included when available were diabetes, current smoker, current alcohol use (>2 drinks per day in the 2 weeks before admission), dyspnea, dependent functional status, history of chronic obstructive pulmonary disease, history of congestive heart failure, previous percutaneous coronary intervention, previous cardiac surgery, hypertension requiring medication, history of transient ischemic attacks, history of stroke, long-term corticosteroid use, bleeding disorder, chemotherapy or radiotherapy within 30 days preoperatively, prior operation, open wound at time of surgery, and disseminated cancer. Operative variables included when available were emergency status of the procedure, work relative value units, total operation time, surgical wound class, American Society of Anesthesiologists class, and free flap type (osseous vs nonosseous).

Analysis of 30-day outcomes in these quintiles was performed (**Table 3**). Surgical complications included superficial, deep, and organ or space surgical site infections; wound disruption; graft, prosthesis, or flap failure; and blood transfusion within 72 hours. Medical complications included pneumonia, unplanned reintubation, pulmonary embolism, mechanical ventilation for longer than 48 hours, renal insufficiency, acute renal failure, urinary tract infection, coma

Table 1. Preoperative Demographics and Comorbidities Stratified by Anesthesia Cohort[a]

Preoperative Variable	Group 1 (n = 126)	Group 2 (n = 125)	Group 3 (n = 128)	Group 4 (n = 125)	Group 5 (n = 126)	*P* Value
Age, mean (SD), y	63.7 (13.2)	61.7 (14.1)	62.0 (13.6)	61.0 (13.5)	59.5 (14.5)	.18
BMI, mean (SD)[b]	25.8 (6.0)	24.8 (4.7)	26.3 (5.6)	26.5 (7.0)	26.7 (5.9)	.10
Obesity (WHO class 1-3)	24 (19.1) [−0.5]	13 (10.4) [−3.2]	30 (23.4) [0.9]	27 (21.6) [0.3]	36 (28.8) [2.5]	.007
WHO classification (BMI)						
0 (<30.0)	102 (81.0)	112 (89.6)	98 (76.6)	98 (78.4)	89 (71.2)	.08
1 (30.0-34.9)	14 (11.1)	7 (5.6)	23 (18.0)	15 (12.0)	25 (20.0)	
2 (35.0-39.9)	6 (4.8)	5 (4.0)	5 (3.9)	7 (5.6)	7 (5.6)	
3 (>40.0)	4 (3.2)	1 (0.8)	2 (1.6)	5 (4.0)	4 (3.2)	
Sex						
Male	87 (69.0)	85 (68.0)	84 (65.6)	91 (72.8)	89 (71.2)	.08
Female	39 (31.0)	40 (32.0)	44 (34.4)	34 (27.2)	36 (28.8)	
Race						
White	75 (89.3)	81 (88.0)	92 (87.6)	96 (81.4)	91 (81.3)	.30
Black	6 (7.1)	4 (4.3)	6 (5.7)	12 (10.2)	15 (13.4)	
Other	3 (3.6)	7 (7.6)	7 (6.7)	10 (8.5)	6 (5.4)	
Preoperative albumin, mean (SD), g/dL	4.0 (0.7)	4.0 (0.6)	4.0 (0.5)	4.0 (0.6)	4.0 (0.5)	.91
Preoperative hematocrit, mean (SD), %	39.9 (5.1)	39.4 (4.8)	39.4 (5.1)	39.3 (4.4)	39.0 (5.1)	.67
Comorbidities						
Diabetes	10 (7.9)	17 (13.6)	14 (10.9)	12 (9.6)	11 (8.7)	.61
Current smoker	9 (27.8)	29 (23.2)	32 (25.0)	33 (26.4)	38 (30.2)	.77
Alcohol consumption of >2 drinks/d	9 (8.6)	10 (8.0)	17 (13.3)	13 (10.4)	18 (14.5)	.40
Dyspnea	10 (14.3)	17 (8.0)	14 (7.0)	12 (6.4)	11 (11.1)	.17
Dependent functional status	4 (3.2)	6 (4.8)	2 (1.6)	2 (1.6)	3 (2.4)	.48
History of COPD	11 (8.7)	9 (7.2)	12 (9.4)	4 (3.2)	10 (7.9)	.36
CHF <30 d	1 (0.8)	1 (0.8)	0	0	1 (0.8)	.73
Previous PCI	8 (7.6)	6 (4.8)	13 (10.2)	5 (4.0)	6 (4.8)	.23
Previous cardiac surgery	5 (4.8)	5 (4.0)	9 (7.0)	6 (4.8)	6 (4.8)	.85
Hypertension	52 (41.3)	57 (45.6)	63 (49.2)	57 (45.6)	60 (47.6)	.77
History of TIA	7 (6.7)	1 (0.8)	5 (3.9)	3 (2.4)	2 (1.6)	.08
History of stroke	2 (1.9)	1 (0.8)	1 (0.8)	2 (1.6)	2 (1.6)	.91
Long-term corticosteroid use	4 (3.2)	3 (2.4)	6 (4.7)	3 (2.4)	9 (7.1)	.26
Bleeding disorder	3 (2.4)	4 (3.2)	3 (2.3)	5 (4.0)	5 (4.0)	.90
Chemotherapy	5 (4.8)	5 (4.0)	1 (8.6)	8 (6.4)	7 (5.6)	.59
Radiotherapy	1 (1.0)	1 (0.8)	2 (1.6)	3 (2.4)	6 (4.8)	.18
Prior operation	5 (4.8)	7 (5.6)	6 (4.7)	5 (4.0)	9 (7.3)	.82
Open wound or wound infection	15 (11.9)	10 (8.0)	10 (7.8)	11 (8.8)	12 (9.5)	.80
Disseminated cancer	14 (11.1)	12 (9.6)	8 (6.2)	6 (4.8)	18 (14.3)	.07

Abbreviations: BMI, body mass index; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; PCI, percutaneous coronary intervention; TIA, transient ischemic attack; WHO, World Health Organization.

SI conversion factors: To convert albumin to grams per liter, multiply by 10; hematocrit to a proportion of 1.0, multiply by 0.01.

[a] Groups 1 through 5 are based on mean (SD) anesthesia times: group 1, 358.1 (175.6) minutes; group 2, 563.2 (27.3) minutes; group 3, 648.9 (24.0) minutes; group 4, 736.5 (26.3) minutes; and group 5, 922.1 (128.1) minutes. Data are presented as number (percentage) of patients unless otherwise indicated. The χ^2 adjusted residuals are reported in brackets for statistically significant variables with significant residuals greater than 1.96.

[b] Calculated as weight in kilograms divided by height in meters squared. Body mass index is available for 629 of 630 patients; 1 patient is unknown in group 5.

for longer than 24 hours, peripheral nerve injury, cardiac arrest, myocardial infarction, deep vein thrombosis, sepsis, septic shock, and stroke. Rates of overall complications, subsequent operation, unplanned readmission, and mortality were also included in this analysis.

All statistical analyses were performed using SPSS statistical software, version 22 (IBM Inc). Independent 2-tailed, unpaired *t* test, cross-tabulation, Pearson χ^2, and Fisher exact tests were used to analyze associations among variables when appropriate. Adjusted residuals were calculated for select preoperative and operative variables and postoperative complications in the χ^2 analyses. Residuals less than −1.96 and greater than 1.96 were considered to be significant. Preoperative and operative variables found to be significant in the bivariate analysis, as well as basic demographic variables, were included in multivariable logistic regression models to deter-

Table 2. Operative Features Stratified by Anesthesia Cohort[a]

Operative Variable	Group 1 (n = 126)	Group 2 (n = 125)	Group 3 (n = 128)	Group 4 (n = 125)	Group 5 (n = 126)	*P* Value
Emergency	0	1 (0.8)	1 (0.8)	0	0	.56
Total operative time, mean (SD), min	400.0 (123.8)	472.5 (37.4)	553.1 (38.1)	636.6 (38.4)	817.0 (118.7)	<.001
Wound class						
Clean	25 (19.8)	32 (25.6)	29 (22.7)	22 (17.6)	22 (17.5)	.09
Clean or contaminated	90 (71.4)	88 (70.4)	95 (74.2)	99 (79.2)	96 (76.2)	
Contaminated	9 (7.1)	3 (2.4)	1 (0.8)	0	5 (4.0)	
Dirty or infected	2 (1.6)	2 (1.6)	3 (2.3)	4 (3.2)	3 (2.4)	
ASA class						
1	2 (1.6)	0	1 (0.8)	0	2 (1.6)	.26
2[b]	21 (16.7)	29 (23.4)	18 (14.1)	23 (18.4)	29 (23.0)	
3	92 (73.0)	86 (69.4)	93 (72.7)	95 (76.0)	80 (63.4)	
4	1 (8.7)	9 (7.3)	16 (12.5)	7 (5.6)	15 (11.9)	
Free flap type						
Osseous	22 (17.5) [−3.0]	24 (19.2) [−2.6]	36 (28.1) [0.1]	42 (33.6) [2.1]	39 (31.0) [3.4]	.009
Nonosseous	98 (77.8) [2.3]	96 (76.8) [2.0]	85 (66.4) [−0.6]	76 (60.8) [−1.9]	68 (54.0) [−1.6]	<.001
Multiple	6 (4.8) [−1.1]	5 (4.0) [−1.5]	7 (5.1) [−0.8]	7 (5.6) [−0.7]	19 (15.1) [4.0]	.003

Abbreviation: ASA, American Society of Anesthesiologists.

[a] Groups 1 through 5 are based on mean (SD) anesthesia times: group 1, 358.1 (175.6) minutes; group 2, 563.2 (27.3) minutes; group 3, 648.9 (24.0) minutes; group 4, 736.5 (26.3) minutes; and group 5, 922.1 (128.1) minutes. Data are presented as number (percentage) of patients unless otherwise indicated. The χ^2 adjusted residuals are reported in brackets for statistically significant variables with significant residuals greater than 1.96.

[b] Data are missing for 1 patient in group 2.

mine the independent association of increased anesthesia duration with complications after free flap surgery of the head and neck. $P < .05$ was considered to be statistically significant.

Results

A total of 630 patients undergoing head and neck free flap surgery from the 2005-2013 NSQIP database had available data on anesthesia duration and were included in the study (mean [SD] age, 61.6 [13.8] years; 436 of 629 [69.3%] male). These patients were ranked based on anesthesia duration and stratified into 5 quintiles. Mean (SD) anesthesia time ranged from 358.1 (175.6) minutes in group 1 to 922.1 (128.1) minutes in group 5. The variability was notably less in groups 2 to 4, with mean (SD) anesthesia durations of 563.2 (27.3) minutes in group 2, 648.9 (24.0) minutes in group 3, and 736.5 (26.3) minutes in group 4 (eFigure in the Supplement).

Preoperative Demographics and Comorbidities

No linear trend in ages was found across the quintiles, as demonstrated in groups 2 to 4, and age overall was not associated with increased or decreased anesthesia duration (Table 1). Of the entire population, 436 patients (69.3%) were male. This male-dominant trend held true in all 5 quintiles, and there was no significant difference in the rate of patient sex across quintiles (87 [69.0%] men in group 1, 85 [68.0%] in group 2, 84 [65.6%] in group 3, 91 [72.8%] in group 4, and 89 [71.2%] in group 5 [of 125 with sex data available]; $P = .08$) (Table 1). White was the most common race, accounting for 435 (85.1%) of all patients in the analysis, followed by black race (43 [8.4%]) and other races (33 [6.5%]). A total of 119 patients had reported unknown race and were not included in statistical analysis. On χ^2 analysis, the distribution of these races was not associated with anesthesia duration (Table 1). The rate of obesity was greatest in group 5 and lowest in group 1, with χ^2 analysis demonstrating a significant difference in the distribution of obesity across cohorts (36 [28.8%] in group 5 vs 24 [19.1%] in group 1, $P = .007$). Adjusted residual values indicate that obesity was associated with the longest durations of anesthesia in group 5 (Table 1). On extreme value analysis comparing only group 1 and group 5, higher rates of obesity were significantly associated with increased anesthesia duration (24 [19.1%] in group 1 vs 36 [28.2%] in group 5, $P = .048$). Mean body mass index and specific World Health Organization obesity categories were not associated with increased or decreased anesthesia duration. Preoperative albumin level and hematocrit were not found to be associated with increased or decreased anesthesia duration.

Univariate analysis of the rates of 19 different preoperative comorbidities across all quintiles (Table 1) demonstrated no associations between comorbidities and increased or decreased anesthesia duration.

Operative Variables

The mean (SD) total operative time was greatest in group 5 (817.0 [118.7] minutes) and lowest in group 1 (400.0 [123.8] minutes). This trend was positively linear across all quintiles, and increased operative time was significantly associated with increased anesthesia duration (mean [SD] operative time, 400.0 [123.8] minutes in group 1 vs 817.0 [118.7] minutes in group 5; $P < .001$) (Table 2). American Society of Anesthesiologists class 3 or 4, nonclean surgical wound, and emergency status of the operation were not associated with increased or decreased anesthesia duration. Cases that involved a single osseous free flap

Table 3. Postoperative Complications Stratified by Anesthesia Cohort[a]

30-Day Postoperative Variable	Group 1 (n = 126)	Group 2 (n = 125)	Group 3 (n = 128)	Group 4 (n = 125)	Group 5 (n = 126)	*P* Value
Overall complications	55 (43.7) [−2.8]	60 (48.0) [−1.7]	75 (58.6) [1.0]	75 (60) [1.3]	80 (63.5) [2.2]	.006
Surgical complications						
Superficial SSI	10 (7.9)	14 (11.2)	7 (5.5)	6 (4.8)	13 (10.3)	.24
Deep incisional SSI	1 (0.8)	3 (2.4)	7 (5.5)	5 (4.0)	5 (4.0)	.29
Organ or space SSI	0	0	3 (2.3)	0	1 (0.8)	.08
Wound disruption	0[−2.6]	4 (3.2) [−0.6]	4 (3.1) [−0.6]	8 (6.4) [1.4]	10 (7.9) [2.4]	.02
Flap failure	8 (6.3)	7 (5.6)	6 (4.7)	5 (4.0)	9 (7.1)	.82
Transfusion within 24 h	32 (25.4) [−4.3]	44 (35.2) [−1.8]	61 (47.7) [1.4]	59 (47.2) [1.3]	70 (55.6) [3.4]	<.001
Total	45 (35.7) [−3.7]	53 (42.4) [−2.0]	71 (55.5) [1.3]	71 (56.8) [1.6]	78 (61.9) [2.9]	<.001
Medical complications						
Pneumonia	9 (7.1)	7 (5.6)	8 (6.2)	8 (6.4)	6 (4.8)	.95
Unplanned reintubation	7 (5.6)	2 (1.6)	3 (3.1)	2 (1.6)	7 (5.6)	.20
Pulmonary embolism	4 (3.2) [2.9]	0[−1.2]	2 (1.6) [0.8]	0[−1.2]	0[−1.2]	.03
Mechanical ventilation >48 h	8 (6.3)	7 (5.6)	7 (5.5)	5 (4.)	8 (6.3)	.93
Renal insufficiency	0	0	0	0	1 (0.8)	.40
Acute renal failure	0	0	0	0	0	NA
UTI	3 (2.4)	2 (1.6)	2 (1.6)	0	1 (0.8)	.51
Coma >24 h	0	0	0	0	0	NA
Peripheral nerve injury	0	0	0	0	0	NA
Cardiac arrest	0	2 (1.6)	1 (0.8)	2 (1.6)	2 (1.6)	.67
Myocardial infarction	1 (0.8)	1 (0.8)	3 (2.3)	0	3 (2.4)	.35
DVT	1 (0.8)	4 (3.2)	1 (0.8)	1 (0.8)	0	.15
Sepsis	4 (3.2)	6 (4.8)	6 (4.7)	2 (1.6)	6 (4.8)	.61
Septic shock	0	1 (0.8)	1 (0.8)	0	1 (0.8)	.74
Stroke	0	0	0	1 (0.8)	1 (0.8)	.55
Total	24 (19.0)	19 (15.2)	20 (15.6)	17 (13.6)	22 (17.5)	.80
Subsequent operation[b]	20 (19.6)	1 (13.1)	9 (9.9)	16 (17.8)	15 (19.0)	.31
Readmitted[c]	6 (6.1)	7 (8.8)	5 (5.6)	10 (12.0)	8 (10.7)	.47
Mortality	1 (0.8) [−0.9]	6 (4.8) [2.9]	3 (2.3) [0.6]	0[−1.7]	1 (0.8) [−0.9]	.03

Abbreviations: DVT, deep vein thrombosis; NA, not applicable; SSI, surgical site infections; UTI, urinary tract infection.

[a] Groups 1 through 5 are based on mean (SD) anesthesia times: group 1, 358.1 (175.6) minutes; group 2, 563.2 (27.3) minutes; group 3, 648.9 (24.0) minutes; group 4, 736.5 (26.3) minutes; and group 5, 922.1 (128.1) minutes. Data are presented as number (percentage) of patients unless otherwise indicated. The χ^2 adjusted residuals are reported in brackets for statistically significant variables with significant residuals greater than 1.96.

[b] Data missing for 184 patients (data available for 102 patients in group 1, 84 in group 2, 91 in group 3, 90 in group 4, and 79 in group 5).

[c] Data missing for 204 patients (data available for 98 patients in group 1, 80 in group 2, 90 in group 3, 83 in group 4, and 75 in group 5).

operation were associated with a positively linear increase in anesthesia duration (22 [17.5%] in group 1 vs 39 [31.0%] in group 5, $P = .009$), with adjusted residual values most significant in group 5. Cases that involved a single nonosseous free flap operation were associated with a negatively linear decrease in anesthesia duration (98 [77.8%] in group 1 vs 68 [54.0%] in group 5; $P < .001$), with adjusted residual values most significant in group 1. Patients in whom multiple free flap operations were performed were most likely to fall into the top quintile with the longest duration of anesthesia (6 [4.8%] in group 1 vs 19 [15.1%] in group 5; $P = .003$), with adjusted residual values most significant in group 5.

Postoperative Complications

The rate of postoperative transfusion within 48 hours was greatest in group 5 (70 [55.6%]) and lowest in group 1 (32 [25.4%]), and this trend was positively linear across quintiles, with adjusted residual values most significantly positive in group 5. The χ^2 analysis demonstrated that this difference in the rates of postoperative transfusion across cohorts was significant ($P < .001$) (Table 3). In addition, the rate of wound disruption was significantly distributed across quintiles, with a positively linear trend occurring in 10 (7.9%) in group 5 and 0 in group 1 ($P = .02$) and adjusted residual values most significantly positive in group 5 (Table 3). Overall surgical complications were also significantly associated with in-

creased anesthesia duration and demonstrated a positively linear trend, occurring in 45 patients (35.7%) in group 1 and 78 (61.9%) in group 5 ($P < .001$) and adjusted residual values most significantly positive in group 5 (Table 3). Distribution of rates of postoperative pulmonary embolism across cohorts was also significant; however, rates were greatest in group 1 (4 [3.2%]) and uniformly 0 in groups 2, 4, and 5 ($P = .03$). Group 3 had pulmonary embolism in 2 patients (1.6%) (Table 3). No other individual medical complications were significantly associated with an increased or decreased anesthesia duration, and rates of overall medical complications were not significantly distributed among quintiles. The overall complication rate was positively linear throughout the quintiles, with the lowest rate in group 1 (55 [43.7%]) and the highest rate in group 5 (80 [63.5%]) and adjusted residual values most significantly positive in group 5. These higher rates of postoperative complications were significantly associated with increased anesthesia duration ($P = .006$) (Table 3). The greatest rate of mortality after free flap surgery of the head and neck was found in group 2 (6 [4.8%]), and the lowest rate was found in group 4 (0) (Table 3). The distribution of mortality rates across quintiles was significant ($P = .03$) (Table 3); however, the trend was not linear. On extreme value analysis comparing only group 1 and group 5, there was no statistical difference between rates of mortality (1 [0.8%] vs 1 [0.8%], $P = .75$) and mean (SD) total work (30.1 [10.9] relative value units in group 1 vs 31.0 [11.3] relative value units in group 5, $P = .51$). In addition, the associations of unplanned readmission (6 [6.1%] in group 1 vs 8 [10.7%] in group 5, $P = .31$) and subsequent operation (20 [19.6%] in group 1 vs 15 [19.0%] in group 5, $P = .47$) with anesthesia duration were not significant (Table 3). The associations of all complications with increased anesthesia duration were significant in group 5. Thus, anesthesia durations of approximately 11 hours or more (group 5 mean minus 2 SDs) were most associated with postoperative complications.

Multivariate Analysis

Binary logistic multivariate analysis was performed to account for age, sex, race, and obesity. Group 1 was used as our reference group, and data reported represent relative risks for group 5. Increased anesthesia duration was an independent risk factor for overall complications (group 5: odds ratio [OR], 1.98; 95% CI, 1.10-3.58; $P = .02$), surgical complications (group 5: OR, 2.46; 95% CI, 1.35-4.46; $P = .003$), and postoperative transfusion (group 5: OR, 2.31; 95% CI, 1.27-4.20; $P = .006$) after accounting for the listed confounders. Wound disruption was not significantly associated with increased or decreased anesthesia duration after multivariate regression (OR, 2.0; $P = .16$). The results of analyses for pulmonary embolism and mortality were not significant, with ORs of approximately 1, because of the nonlinear trend in complication rates associated with increasing anesthesia duration.

Discussion

Microvascular reconstructive surgery has been developed and refined during the past 50 years with the aim of decreasing morbidity while maximizing flap transfer success and clinical benefit. The current incidence of postoperative flap loss has been reported as less than 3%.[1,4,18-20] This success is in part attributable to the advent of modern flap monitoring techniques and astute perioperative surgical care, as well as improved surgical techniques. The association between prolonged operative time and postoperative complications has long been investigated in the literature.[21-24] Increased operative duration has specifically been shown to be a risk factor for morbidity in free flap procedures, with existing literature citing increased rates of rhabdomyolysis, fluid and electrolyte disturbances, deep vein thrombosis, and hypothermia.[14,25-39]

Although anesthesia duration is associated with operative time, few studies[10,33] have specifically evaluated this measure as a risk factor for morbidity. Patients who have a tumultuous anesthetic course and protracted time to extubation after surgical closure may be at risk for certain postoperative complications. In 2014, a study by Kim et al[33] that also used quintiles examined the effect of anesthesia time on free flap surgery of all sites, concluding that longer anesthesia times conveyed a greater risk of postoperative transfusion. Another review[10] characterized prolonged operative time as an independent risk factor for free flap failure. The population receiving free flaps of the head and neck is unique with its own collection of clinical characteristics and comorbidities. Minimal literature exists on the association of anesthesia times with free flap surgery in this distinct population.

Compared with other surgical sites, the complexity of head and neck microvascular reconstruction may provide for an inherently long operation. These cases are also more likely to require osseous reconstruction in addition to soft tissue, further lengthening the procedure. This was observed in our data set, in which the mean anesthesia duration was nearly 60 minutes longer when an osseous flap was used. In addition to flap type, selection of donor site is a major determinant of length of procedure. Operative time can be significantly reduced if the flap can be harvested at the same time as the dissection of the recipient site rather than each step being performed serially after patient repositioning.

Anesthesia duration may also be extended for patients who are poor surgical candidates or may be otherwise at risk for a more complex operative course. In our analysis of patient comorbidities, only obesity was significantly associated with increased anesthesia duration. Obesity can be intuitively understood as a risk factor for increased anesthesia duration and other perioperative complications. However, multivariate regression analysis was used to account for the disparity in distribution of obesity and flap type across groups, demonstrating that prolonged anesthesia may be an independent predictor of overall postoperative complications.

With regard to outcomes, our results revealed no difference in mortality between group 1 and group 5. In addition, our data corroborate the findings of Kim et al[33] in demonstrating an insignificant association between increasing anesthesia time and risk of flap loss. However, Kim et al[33] did not find increased anesthesia time to be a risk factor for postoperative complications in their overall free flap surgery population. Our results show that patients undergoing head and neck surgery

may be particularly sensitive to duration of anesthesia, with increased anesthesia time predictive of complications overall. When specific postoperative complications are grouped, only the rates of surgical complications exhibited the same significance as overall complications. This finding suggests that medical complications are more likely to be a function of the patient's preoperative health status than the operative course.

When looking at each specific outcome individually, we found that only the rate of perioperative transfusion was significant after multivariate regression. The incidence of intraoperative and postoperative transfusion, which serves as a surrogate for blood loss, has been well studied for various operative procedures as a quality indicator for surgical performance.[24,33,34] Despite advancements in microvascular technique and improvement in outcomes, blood transfusion is still required in a significant number of patients undergoing free flap surgery.[35-37] Our analysis showed a similarly high rate of transfusion (mean of 42%) with a significant linear trend in the incidence across the 5 quintiles ranging from 25.4% to 55.6%. Multivariate analysis showed that increased anesthesia duration was an independent risk factor for perioperative transfusion, with 2.39 times the risk in group 5 vs group 1. Known risks of allogenic blood transfusion include cancer recurrence, acute lung injury, and increased incidence of postoperative infection. Transfusion-related immune suppression appeared to be the cause of these postoperative consequences.[38,39] Minimizing blood loss during surgery has been encouraged as a result of that finding.

These results highlight the need for an awareness of the perioperative and nonsurgical factors that may extend anesthesia time and tactics that promote intraoperative efficiency. One such strategy involves selection of a donor site amenable to concurrent harvesting and implementation of a 2-team approach. Studies[40-42] have found that this is an effective strategy in reducing operative time and thereby reducing overall anesthesia duration. The number of microvascular anastomoses and defect closure that will be required should also be considered in donor site selection. Ultimately, meticulous preoperative planning and preparation should allow surgeons to reduce operating room time regardless of other nonsurgical factors out of their control.

Limitations

The limitations of this study are intrinsic to the database from which the information was taken. As with any retrospective analysis, the possibility of bias cannot be eliminated from the data extracted from the NSQIP registry. The registry also lacks information of specific interest to free flap surgery, including flap failure timing, reason for flap failure, and donor site morbidity. Furthermore, long-term results of microvascular and reconstructive surgery could not be studied because the NSQIP data are limited to a 30-day postoperative period. Last, the use of blood transfusion in this database is coded for all patients receiving a transfusion intraoperatively or within 24 hours, and it should be considered that not all these occurrences necessarily represent a postoperative complication.

Conclusions

This review of 630 patients undergoing head and neck free flap surgery revealed that increased anesthesia duration may be an independent risk factor for postoperative complications, in particular surgical complications and the need for postoperative transfusion. Detailed surgical planning, avoidance of excessive blood loss, and reduced anesthesia times, particularly to less than 11 hours, should be the goal when performing microvascular free flap reconstruction of the head and neck.

ARTICLE INFORMATION

Accepted for Publication: August 1, 2017.

Published Online: October 5, 2017. doi:10.1001/jamafacial.2017.1607

Author Contributions: Dr Brady had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Brady, Desai, Crippen, Eloy, Gubenko, Park.
Acquisition, analysis, or interpretation of data: Brady, Desai, Crippen, Baredes, Park.
Drafting of the manuscript: Brady, Desai, Crippen, Park.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Brady, Desai, Crippen, Park.
Administrative, technical, or material support: Baredes, Park.
Study supervision: Desai, Eloy, Gubenko, Park.

Conflict of Interest Disclosures: None reported.

REFERENCES

1. Bui DT, Cordeiro PG, Hu QY, Disa JJ, Pusic A, Mehrara BJ. Free flap reexploration: indications, treatment, and outcomes in 1193 free flaps. *Plast Reconstr Surg*. 2007;119(7):2092-2100.

2. Offodile AC II, Aherrera A, Wenger J, Rajab TK, Guo L. Impact of increasing operative time on the incidence of early failure and complications following free flap surgery? a risk factor analysis of 2,008 patients from the ACS-NSQIP database. *Microsurgery*. 2017;37(1):12-20.

3. Mücke T, Ritschl LM, Roth M, et al. Predictors of free flap loss in the head and neck region: A four-year retrospective study with 451 microvascular transplants at a single centre. *J Craniomaxillofac Surg*. 2016;44(9):1292-1298.

4. Dowthwaite SA, Theurer J, Belzile M, et al. Comparison of fibular and scapular osseous free flaps for oromandibular reconstruction: a patient-centered approach to flap selection. *JAMA Otolaryngol Head Neck Surg*. 2013;139(3):285-292.

5. Pattani KM, Byrne P, Boahene K, Richmon J. What makes a good flap go bad? a critical analysis of the literature of intraoperative factors related to free flap failure. *Laryngoscope*. 2010;120(4):717-723.

6. Rosenberg AJ, Van Cann EM, van der Bilt A, Koole R, van Es RJ. A prospective study on prognostic factors for free-flap reconstructions of head and neck defects. *Int J Oral Maxillofac Surg*. 2009;38(6):666-670.

7. Clark JR, McCluskey SA, Hall F, et al. Predictors of morbidity following free flap reconstruction for cancer of the head and neck. *Head Neck*. 2007;29(12):1090-1101.

8. Eckardt A, Fokas K. Microsurgical reconstruction in the head and neck region: an 18-year experience with 500 consecutive cases. *J Craniomaxillofac Surg*. 2003;31(4):197-201.

9. Bozikov K, Arnez ZM. Factors predicting free flap complications in head and neck reconstruction. *J Plast Reconstr Aesthet Surg*. 2006;59(7):737-742.

10. Wong AK, Joanna Nguyen T, Peric M, et al. Analysis of risk factors associated with microvascular free flap failure using a multi-institutional database. *Microsurgery*. 2015;35(1):6-12.

11. Chan MM, Hamza N, Ammori BJ. Duration of surgery independently influences risk of venous thromboembolism after laparoscopic bariatric surgery. *Surg Obes Relat Dis*. 2013;9(1):88-93.

12. Daley BJ, Cecil W, Clarke PC, Cofer JB, Guillamondegui OD. How slow is too slow? correlation of operative time to complications: an

analysis from the Tennessee Surgical Quality Collaborative. *J Am Coll Surg*. 2015;220(4):550-558.

13. Routh JC, Bacon DR, Leibovich BC, Zincke H, Blute ML, Frank I. How long is too long? the effect of the duration of anaesthesia on the incidence of non-urological complications after surgery. *BJU Int*. 2008;102(3):301-304.

14. Procter LD, Davenport DL, Bernard AC, Zwischenberger JB. General surgical operative duration is associated with increased risk-adjusted infectious complication rates and length of hospital stay. *J Am Coll Surg*. 2010;210(1):60-65.e1-2.

15. Hagau N, Longrois D. Anesthesia for free vascularized tissue transfer. *Microsurgery*. 2009;29(2):161-167.

16. Gooneratne H, Lalabekyan B, Clarke S, Burdett E. Perioperative anaesthetic practice for head and neck free tissue transfer: a UK national survey. *Acta Anaesthesiol Scand*. 2013;57(10):1293-1300.

17. Motakef S, Mountziaris PM, Ismail IK, Agag RL, Patel A. Perioperative management for microsurgical free tissue transfer: survey of current practices with a comparison to the literature. *J Reconstr Microsurg*. 2015;31(5):355-363.

18. Frederick JW, Sweeny L, Carroll WR, Peters GE, Rosenthal EL. Outcomes in head and neck reconstruction by surgical site and donor site. *Laryngoscope*. 2013;123(7):1612-1617.

19. Andree C, Langer S, Seidenstuecker K, et al. A single center prospective study of bilateral breast reconstruction with free abdominal flaps: a critical analysis of 144 patients. *Med Sci Monit*. 2013;19:467-474.

20. Fischer JP, Sieber B, Nelson JA, et al. A 15-year experience of complex scalp reconstruction using free flap surgery-analysis of risk factors for complications. *J Reconstr Microsurg*. 2013;29:89-97.

21. Peersman G, Laskin R, Davis J, Peterson MG, Richart T. Prolonged operative time correlates with increased infection rate after total knee arthroplasty. *HSS J*. 2006;2(1):70-72.

22. Selim M. Perioperative stroke. *N Engl J Med*. 2007;356(7):706-713.

23. Dexter SP, Martin IG, Marton J, McMahon MJ. Long operation and the risk of complications from laparoscopic cholecystectomy. *Br J Surg*. 1997;84(4):464-466.

24. Ball CG, Pitt HA, Kilbane ME, Dixon E, Sutherland FR, Lillemoe KD. Peri-operative blood transfusion and operative time are quality indicators for pancreatoduodenectomy. *HPB (Oxford)*. 2010;12(7):465-471.

25. Lynch RJ, Englesbe MJ, Sturm L, et al. Measurement of foot traffic in the operating room: implications for infection control. *Am J Med Qual*. 2009;24(1):45-52.

26. Carty MJ, Hivelin M, Dumontier C, et al. Lessons learned from simultaneous face and bilateral hand allotransplantation. *Plast Reconstr Surg*. 2013;132(2):423-432.

27. Balasubramanian D, Thankappan K, Kuriakose MA, et al. Reconstructive indications of simultaneous double free flaps in the head and neck: a case series and literature review. *Microsurgery*. 2012;32(6):423-430.

28. Baumann DP, Crosby MA, Selber JC, et al. Optimal timing of delayed free lower abdominal flap breast reconstruction after postmastectomy radiation therapy. *Plast Reconstr Surg*. 2011;127(3):1100-1106.

29. Malhotra A, Chhaya N, Nsiah-Sarbeng P, Mosahebi A. CT-guided deep inferior epigastric perforator (DIEP) flap localization: better for the patient, the surgeon, and the hospital. *Clin Radiol*. 2013;68(2):131-138.

30. Fogarty BJ, Khan K, Ashall G, Leonard AG. Complications of long operations: a prospective study of morbidity associated with prolonged operative time (>6 h). *Br J Plast Surg*. 1999;52(1):33-36.

31. Wang WZ, Baynosa RC, Zamboni WA. Update on ischemia-reperfusion injury for the plastic surgeon: 2011. *Plast Reconstr Surg*. 2011;128(6):685e-692e.

32. Siemionow M, Arslan E. Ischemia/reperfusion injury. *Microsurgery*. 2004;24(6):468-475.

33. Kim BD, Ver Halen JP, Grant DW, Kim JY. Anesthesia duration as an independent risk factor for postoperative complications in free flap surgery: a review of 1,305 surgical cases. *J Reconstr Microsurg*. 2014;30(4):217-226.

34. LaPar DJ, Crosby IK, Ailawadi G, et al; Investigators for the Virginia Cardiac Surgery Quality Initiative. Blood product conservation is associated with improved outcomes and reduced costs after cardiac surgery. *J Thorac Cardiovasc Surg*. 2013;145(3):796-803.

35. Perisanidis C, Mittlböck M, Dettke M, et al. Identifying risk factors for allogenic blood transfusion in oral and oropharyngeal cancer surgery with free flap reconstruction. *J Oral Maxillofac Surg*. 2013;71(4):798-804.

36. Shah MD, Goldstein DP, McCluskey SA, et al. Blood transfusion prediction in patients undergoing major head and neck surgery with free-flap reconstruction. *Arch Otolaryngol Head Neck Surg*. 2010;136(12):1199-1204.

37. Fischer JP, Nelson JA, Sieber B, et al. Transfusions in autologous breast reconstructions: an analysis of risk factors, complications, and cost. *Ann Plast Surg*. 2014;72(5):566-571.

38. Hébert PC, Yetisir E, Martin C, et al; Transfusion Requirements in Critical Care Investigators for the Canadian Critical Care Trials Group. Is a low transfusion threshold safe in critically ill patients with cardiovascular diseases? *Crit Care Med*. 2001;29(2):227-234.

39. Hébert PC, Wells G, Blajchman MA, et al; Transfusion Requirements in Critical Care Investigators, Canadian Critical Care Trials Group. A multicenter, randomized, controlled clinical trial of transfusion requirements in critical care. *N Engl J Med*. 1999;340(6):409-417.

40. Horn D, Jonas R, Engel M, Freier K, Hoffmann J, Freudlsperger C. A comparison of free anterolateral thigh and latissimus dorsi flaps in soft tissue reconstruction of extensive defects in the head and neck region. *J Craniomaxillofac Surg*. 2014;42(8):1551-1556.

41. Wong KK, Enepekides DJ, Higgins KM. Cost-effectiveness of simultaneous versus sequential surgery in head and neck reconstruction. *J Otolaryngol Head Neck Surg*. 2011;40(1):48-53.

42. Wilkman T, Törnwall J, Vuola J, Lassus P. The free scapular flap with latissimus muscle reduces fistulas in mandibular reconstruction. *J Plast Reconstr Aesthet Surg*. 2016;69(6):802-808.