Thirty-Day Outcomes following Upper Extremity Flap Reconstruction

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Abstract

Introduction Flap reconstructions of upper extremity defects are challenging procedures. It is important to understand the surgical outcomes of upper extremity flap reconstruction, as well as associations between preoperative/perioperative variables and complications.

Materials and Methods The National Surgical Quality Improvement Program (NSQIP) database was queried for patients from 2005 to 2016 who underwent flap reconstruction of an upper extremity defect. Patient and perioperative variables were collected for identified patients and assessed for associations with rates of any complication and major complications.

Results On multivariate analysis, American Society of Anesthesiologists (ASA) classification >2, bleeding disorder, preoperative steroid use, free flap reconstruction, wound classification other than clean, and nonplastic surgeon specialty were independently associated with any complications. Bleeding disorder, ASA classification >2, male gender, wound classification other than clean, and preoperative anemia were independently associated with major complications. Free flap reconstruction was associated with increased length of stay, operative time, any complications, transfusions, and unplanned reoperations.

Conclusion There is an association between complications in patients undergoing upper extremity free flap reconstruction and ASA classification >2, preoperative anemia, preoperative steroid use, bleeding disorders, and contaminated wounds. Male patients may require more thorough counseling in activity restriction following reconstruction. Free flaps for upper extremity reconstruction will require increased planning to reduce the chance of complications.

Keywords
- microsurgery
- upper extremity
- 30-day outcomes

Introduction

Upper extremity soft tissue defects are a reconstructive challenge and can have a significant impact on an individual's functionality and quality of life.[1,2] The majority of upper extremity defects are caused by trauma from agriculture or industrial accidents, and the most frequent permanent disability from these accidents is to the hands.[3] As reconstructive techniques have improved, a greater numbers of limbs are able to be salvaged, and the need for amputation continues to decrease. Frequently, with upper extremity trauma, tumor extirpation, and infection, the reconstructive surgeon is left with tissue defects requiring pedicled or free flaps to give the best chance for coverage of vital structures, obliteration of dead space, and return of form and function.[4-8]

With increasing prevalence of flap reconstruction for soft tissue defects of the upper extremities, surgical outcomes

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data and predictors of complications are of paramount importance.[9] Outcomes following hand and wrist surgery have been documented in the literature,[10] but no literature exists specifically focusing on the outcomes of upper extremity flap procedures. Contemporary complication rates and the associated variables will assist the reconstructive surgeon with patient counseling and education. In this study, patient comorbidities, overall health status and flap type were assessed for their association with complications after upper extremity flap procedures. The American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) database was used to determine patient factors related to any complications and major complications.

Materials and Methods

The data for this study was obtained using the ACS NSQIP database. Exemption from the Institutional Review Board was attained because the NSQIP data contains only deidentified patient information. ACS NSQIP obtains postoperative data for up to 30 days using a prospective, peer-controlled, validated database that accumulates information from ~680 participating sites in 2016.[11] The history and methods of the NSQIP database have been described in detail previously.[12,13]A retrospective study was conducted using the NSQIP database for patients undergoing soft tissue reconstruction of the upper extremity between 2005 and 2016.

Patient Identification

The NSQIP participant data files were obtained from 2005 through 2016. The database was queried for patients undergoing soft tissue reconstruction of the upper extremity. Patients were included who had a muscle, myocutaneous, or fasciocutaneous flap of the upper extremity using the Current Procedural Terminology (CPT) code 15736.Additionally, we included patients who had an upper extremity free flap, island flap, or neurovascular pedicle flap (CPT: 15740, 15750, 15756, 15757,15758) and also had an International Classification of Diseases (ICD-9 or ICD-10) code associated with upper extremity pathology (►**Supplementary Tables S1** and **S2**, available in the online version).

Variables

We identified patient and perioperative variables that were associated with 30-day complication rates. Variables selected for analysis included patient demographics (age, gender, and body mass index [BMI]), comorbidities (diabetes, smoking, hypertension, bleeding disorders, pr eoperative steroid use, whether the patient was already admitted to the hospital, and American Society of Anesthesiologists [ASA] classification). ASA classification is based on the anesthesiologist's assessment of the patient's systemic health and is assigned at the time of surgery.[14] Patients were also assessed for preoperative anemia (hematocrit <30) and malnutrition (albumin <3.5). Perioperative details were collected and included type of procedure and specialty of the surgeon performing the operation.

Outcomes

The dependent variables included a variety of complications within 30 days of the index surgery. Our primary outcome was any complication. Secondary outcomes included wound complications, medical complications, and major complications. Wound complications included dehiscence, superficial wound infection, wound infection, and organ space infection. Medical complications were categorized into neurologic, cardiac, renal, respiratory, venous thromboembolism and infectious. Major complications were defined as any complication requiring unplanned readmission or reoperation, flap/graft failure, deep organ space infection, or death. Regarding the outcome variable "flap/graft failure," national discrepancies in the NSQIP data recording led to inaccuracies in this outcome variable. Prior to 2010, flap/graft failure was included as a complication. However, beyond 2010 this variable was inaccurately recorded in the NSQIP database and not included in total complications.[15] Patients were also evaluated for length of postoperative stay and operative time. We also performed a subgroup analysis of patients undergoing free flap reconstruction compared with pedicled flaps to examine differences in complications.

Statistical Analysis

All statistical analyses were performed using SAS Version 9.4 (Cary, North Carolina, United States). Cross-tabulation and descriptive analyses were performed to characterize demographic information and identify missing or deficient variables.

Univariate associations were calculated using chi-square analysis and Fisher's exact tests where appropriate. Multivariate logistic regression models were created to identify independent associations of any complication and major complications and to adjust for confounders. Patients were stratified for age and operative time based on quartile. BMI was stratified based on weight classification (<18.5 underweight, 18.5—<25 normal, 25—<30 overweight, 30—<35 class I obesity, 35—<40 class II obesity, ≥40 class III obesity). For the multivariable model, age ≥ 55 years, operative time in the longest quartile (>200 minutes), BMI > 25, and ASA class >2 were included in the analysis. Odds ratios with their 95% confidence intervals and *p*-values were determined for these models, with a *p*-value of less than 0.05 set as significant.

Results

Patient Demographics

Between 2005 and 2016, 825 upper extremity soft tissue reconstruction operations were identified in the NSQIP database. Free flaps were performed in 151 patients (18.3%) and pedicled flaps in 674 patients (81.7%). Men and women represented 61 and 39%, respectively. A total of 77% of patients were white and 56% of patients had an ASA class of either 1 or 2. Most procedures were performed by plastic surgeons (58%) under general anesthesia (88%) involving nonclean surgical wounds (88%) (►**Table 1**). Other than plastic surgery, orthopaedic surgery was the next most common specialty performing the reconstructions, followed by vascular surgery and general surgery.

Table 1 Patient demographics, comorbidities, and perioperative details of patients with any complication

	No complication (*n* = 674)	%	Any complication (*n* = 151)	%	Overall (*n* = 825)	%	*p*-Value
Female	270	40.1	54	35.8	324	39.3	
Male	404	59.9	97	64.2	501	60.7	0.357
Age							
Youngest 25% (<39)	238	35.3	61	40.4	299	36.2	
25–50% (39–48)	162	24.0	25	16.6	187	22.7	
50–75% (48–59)	131	19.4	35	23.2	166	20.1	
Oldest 25% (>59)	143	21.2	30	19.9	173	21.0	0.18
BMI							
0—<18.5	23	3.4	10	6.6	33	4.0	
1—18.5–25.0	192	28.5	50	33.1	242	29.3	
2—25.0–30	243	36.1	50	33.1	293	35.5	
3—30–35.0	121	18.0	21	13.9	142	17.2	
4—35.0–40	66	9.8	13	8.6	79	9.6	
5—>40	29	4.3	7	4.6	36	4.4	0.33
Bleeding disorder	13	1.9	11	7.3	24	2.9	*0.002*
No	661	98.1	140	92.7	801	97.1	
Preoperative steroids	22	3.3	14	9.3	36	4.4	*0.003*
No	652	96.7	137	90.7	789	95.6	
Hypertension—no	235	34.9	54	35.8	289	35.0	0.851
No	439	65.1	97	64.2	536	65.0	
Smoker	175	26.0	49	32.5	224	27.2	0.107
No	499	74.0	102	67.5	601	72.8	
Diabetic	68	10.1	19	12.6	87	10.5	0.38
No	606	89.9	132	87.4	738	89.5	
Renal failure	13	1.9	7	4.6	20	2.4	0.072
No	661	98.1	144	95.4	805	97.6	
ASA classification				0.0	0	0.0	
1	88	13.1	12	7.9	100	12.1	
2	319	47.3	46	30.5	365	44.2	
3	248	36.8	82	54.3	330	40.0	
4	19	2.8	11	7.3	30	3.6	*<0.001*
Operative time (minutes)							
Shortest 25% (<107)	148	22.0	11	7.3	159	19.3	
25–75% (108–199)	265	39.3	46	30.5	311	37.7	
Longest 25% (> 200)	108	16.0	50	33.1	158	19.2	*<0.001*
Albumin							
≥3.5	199	29.5	35	23.2	234	28.4	
<3.5	42	6.2	27	17.9	69	8.4	
Missing	433	64.2	89	58.9	522	63.3	*<0.001*
Hematocrit							
<30	475	70.5	94	62.3	569	69.0	
>30	28	4.2	25	16.6	53	6.4	
Missing	171	25.4	32	21.2	203	24.6	*<0.001*

(Continued)

Table 1 *(Continued)*

	No complication (*n* = 674)	%	Any complication (*n* = 151)	%	Overall (*n* = 825)	%	*p*-Value
Wound classification							
Clean	473	86.2	76	13.8	549	66.6	
Clean contaminated	69	67	34	33	103	12.5	
Contaminated	78	82.1	17	17.9	95	11.5	
Dirty/infected	54	69.2	24	30.8	78	9.5	*<0.001*
Pedicled flap	558	82.8	106	70.2	664	80.5	
Free flap	106	15.7	45	29.8	151	18.3	*<0.001*
Skin graft	141	20.9	36	23.8	177	21.5	
No	533	79.1	115	76.2	648	78.5	0.443
Plastic surgery	415	61.6	64	42.4	479	58.1	
Other specialty	259	38.4	87	57.6	346	41.9	*<0.001*

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index.

Table 2 Subgroup analysis of complications in free flap patients

Complications	Free Flap (*n* = 151)	%	Pedicled (*n* = 674)	%	Overall (*n* = 825)	%	*p*-Value
Mortality	0	0.0	4	0.6	4	0.5	1
Any complication	45	29.8	106	15.7	151	12.8	*<0.001*
Major complication	15	9.9	49	7.7	64	7.3	0.311
Unplanned readmission	7	4.6	29	4.3	36	4.4	0.827
Unplanned reoperation	12	7.9	21	3.1	33	4.0	*0.011*
Medical complication	4	2.6	28	4.2	32	3.9	0.489
Neurological	0	0.0	0	0.0	0	0.0	
Cardiac	0	0.0	0	0.0	0	0.0	
Renal	0	0.0	1	0.1	1	0.1	
Respiratory	3	2.0	12	1.8	15	1.8	
VTE	0	0.0	3	0.4	3	0.4	
Infection	1	0.7	15	2.2	16	1.9	
Wound complication	5	3.3	45	6.7	50	6.1	0.133
Superficial infection	4	2.6	16	2.4	20	2.4	
Wound infection	0	0.0	6	0.9	6	0.7	
Organ space infection	0	0.0	5	0.7	5	0.6	
Dehiscence	1	0.7	15	2.2	16	1.9	
Transfusion	30	19.9	38	5.6	68	8.2	*<0.001*

Abbreviation: VTE, venous thromboembolism.

Among the patients who underwent flap coverage, 151 (18.3%) suffered a complication and 64 (7.3%) suffered a major complication within 30 days of their index procedure. Of these, 36 patients had an unplanned readmission and 33 had a reoperation. Some patients had both an unplanned readmission and unplanned reoperation (►**Table 2**).

Univariate Analysis

Preoperative bleeding disorder, preoperative steroid use, ASA classification >2, preoperative anemia, free flap reconstruction, operative time > 199 minutes, wound classification other than clean, and reconstruction performed by a nonplastic surgeon were all associated with any complications (►**Table 1**). Male gender, bleeding disorder, ASA classification > 2, preoperative anemia, wound classification other than clean and nonplastic surgeon performing the reconstruction were all associated with major complications (►**Table 3**). Albumin level was excluded from multivariate analysis because a majority of patients were missing the value.

Multivariate Analysis

Multivariate regression identified variables independently associated with total and major complications following upper extremity soft tissue reconstruction (►**Table 4**). ASA

Table 3 Patient demographics, comorbidities, and perioperative details of patients with any major complication

	No complication (*n* = 761)	%	Complication (*n* = 64)	%	Overall (*n* = 825)	%	*p*-Value
Female	309	40.6	15	23.4	324	39.3	
Male	452	59.4	49	76.6	501	60.7	*0.003*
Age							
Youngest 25% (<39)	277	36.4	22	34.4	299	36.2	
25–50% (39–48)	175	23.0	12	18.8	187	22.7	
50–75% (48–59)	150	19.7	16	25.0	166	20.1	
Oldest 25% (>59)	159	20.9	14	21.9	173	21.0	0.709
BMI category		0.0		0.0			
0—<18.5	29	3.8	4	6.3	33	4.0	
1—18.5–25.0	219	28.8	23	35.9	242	29.3	
2—25.0–30	271	35.6	22	34.4	293	35.5	
3—30–35.0	131	17.2	11	17.2	142	17.2	
4—35.0–40	78	10.2	1	1.6	79	9.6	
5—>40	33	4.3	3	4.7	36	4.4	0.33
Bleeding disorder	16	2.1	8	12.5	24	2.9	
No	745	97.9	56	87.5	801	97.1	*<0.001*
Preoperative steroids	31	4.1	5	7.8	36	4.4	
No	730	95.9	59	92.2	789	95.6	0.19
Hypertension	262	34.4	27	42.2	289	35.0	
No	499	65.6	37	57.8	536	65.0	0.221
Smoker	203	26.7	21	32.8	224	27.2	
Nonsmoker	558	73.3	43	67.2	601	72.8	0.306
Diabetes	78	10.2	9	14.1	87	10.5	
No	683	89.8	55	85.9	738	89.5	0.393
Renal failure	17	2.2	3	4.7	20	2.4	
No	744	97.8	61	95.3	805	97.6	0.198
ASA classification		0.0		0.0	0	0.0	
1	96	12.6	4	6.3	100	12.1	
2	347	45.6	18	28.1	365	44.2	
3	293	38.5	37	57.8	330	40.0	
4	25	3.3	5	7.8	30	3.6	*0.003*
Operative time (minutes)							
Shortest 25% (<107)	154	22.8	5	3.3	159	19.3	
25–75% (108–199)	289	42.9	22	14.6	311	37.7	
Longest 25% (> 200)	141	20.9	17	11.3	158	19.2	0.07
Albumin							
≥3.5	217	28.5	17	26.6	234	28.4	
<3.5	55	7.2	14	21.9	69	8.4	
Missing	489	64.3	33	51.6	522	63.3	*<0.001*
Hematocrit							
<30	530	69.6	39	60.9	569	69.0	
>30	39	5.1	14	21.9	53	6.4	
Missing	192	25.2	11	17.2	203	24.6	*<0.001*
Wound classification							
Clean	521	94.9	28	5.1	549	66.6	
Clean contaminated	84	81.6	19	18.5	103	12.5	

Table 3 (*Continued*)

	No complication (*n* = 761)	%	Complication (*n* = 64)	%	Overall (*n* = 825)	%	*p*-Value
Contaminated	89	93.7	6	6.3	95	11.5	
Dirty/Infected	67	85.9	11	14.1	78	9.5	*<0.001*
Free flap	136	17.9	15	23.4	151	18.3	
Pedicled	625	82.1	49	76.6	674	81.7	0.311
Skin graft	161	21.2	16	25.0	177	21.5	
No	600	78.8	48	75.0	648	78.5	0.443
Plastics	445	58.5	34	53.1	479	58.1	
Other specialty	316	41.5	30	46.9	346	41.9	*<0.001*

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index.

Table 4 Multivariate analysis of patients

	Any complication (*n* = 151)			Major complication (*n* = 64)		
	OR	95% CI	*p*-Value	OR	95% CI	*p*-Value
Male	1.19	0.8–1.78	0.289	2.12	1.23–3.68	0.003
Old age	0.93	0.55–1.59	0.673			
ASA classification > 2	1.63	1.2–2.21	0.007	1.57	1.07–2.29	0.02
Obesity	0.90	0.58–1.39	0.707			
Diabetes	0.84	0.43–1.62	0.666			
Smoking	1.21	0.79–1.84	0.363			
Hypertension	0.72	0.5–1.14	0.156			
Steroid use	2.61	1.22–5.6	0.006			
Bleeding disorders	3.14	1.28–7.71	0.022	4.36	1.67–11.35	0.002
Associated skin graft	0.93	0.59–1.47	0.877			
Free flap	3.37	2.11–5.37	<.001			
Malnutrition	1.86	0.98–3.52	0.084			
Anemia	2.21	1.13–4.31	0.031	3.42	1.65–7.09	0.001
Specialty (other than plastic surgery)	1.49	1.2–1.86	<.001	1.04	0.76–1.42	0.806
Wound classification other than clean	2.01	1.32–3.07	0.001	2.12	1.23–3.68	0.007

Abbreviations: ASA, American Society of Anesthesiologists; CI, confidence interval; OR, odds ratio.

classification >2, steroid use, bleeding disorder, free flap reconstruction, preoperative anemia, wound classification other than clean, and nonplastic surgeon specialty were independently associated with any complications. Male gender, ASA classification >2, bleeding disorders, wound classification other than clean, and preoperative anemia were independently associated with major complications.

Subgroup analysis of free flap versus nonfree flap reconstruction is shown in ►**Table 5**. Rate of any complications, reoperation, and transfusions were all found to be higher in free flap reconstructions. The rate of major complication was not significantly higher in free flap reconstructions. Free flap reconstruction took an average of 270 minutes longer than nonfree flap reconstruction. Free flap reconstruction was also associated with a 2.6 day longer hospitalization compared with nonfree flap reconstruction (►**Table 5**).

Table 5 Subgroup analysis of operative time and length of stay in free flap patients

	Mean	Median	SD	*p*-Value
Operative time (minutes)				
Nonfree flap (*n* = 674)	167.93	116.5	154.99	
Free flap (*n* = 151)	437.25	454	176.77	<0.001
Length of stay (days)				
Nonfree flap (*n* = 674)	3.97	1	10.27	
Free flap (*n* = 151)	6.58	6	4.96	0.002

Abbreviation: SD, standard deviation.

Discussion

The NSQIP database is designed and validated for use in improving quality across US hospitals, making it an ideal

platform for assessing associations between outcomes and preoperative and perioperative risk factors.[12,13,16,17]Previous literature using this database identified the complication rate in hand and wrist surgery to be ~2.5% in a large cohort of 10,646 patients.[10] Injuries that require flap coverage for soft tissue defects are often more complex than the majority of hand/wrist operations. Therefore, higher complication rates may exist in upper extremity flap reconstruction than in general hand/wrist surgery. Our study supported this, noting that the rate of any complications in upper extremity flap coverage cases was 18.3%. This study represents a step towards identifying variables that could contribute to this high complication rate.

Patient characteristics associated with any complication following upper extremity flap coverage included preoperative steroid use, bleeding disorder, preoperative anemia, ASA classification >2, and any wound classification other than clean. Patient characteristics associated with major complications were similar with male sex also associated and steroid use excluded. High ASA classification values have consistently been shown to be associated with complications in surgery, as well as in certain upper extremity operations.[18-20]Preoperative anemia and preoperative steroid use have been found to have associations with unplanned readmissions in hand surgery.[21] They likely represent characteristics of patients with poor overall functional status who should be optimized for their surgery and given close attention in the postoperative period. Bleeding disorders represent a difficult challenge in all surgery. Proper hemostasis, surgical technique, and postoperative care are paramount in preventing complications in patients with bleeding disorders.[22,23]Males are reported to have higher incidence of trauma to their hands and upper extremities than females, likely due to a higher chance of participation in activities with greater risk of upper extremity injury.[24,25]They may need to be counseled more closely to avoid risky use of their upper extremity during the rehabilitation period. Wounds considered "unclean" have an association with an increase in complications. Proper debridement and cleaning of wounds is one of the most important factors in success in upper extremity reconstruction.[7]

Longer operative times were found to have higher complication rates as has been shown previously in the literature.[26,27]Careful planning and diligent communication in the operating room should be used to reduce anesthesia and operating times in these complex cases. Nonplastic surgeons had an independent association with any complications, though not major complications. Complex reconstructive cases should be reserved for the most skilled and experienced surgeons to maximize chances of success.

Free flap reconstruction was associated with a higher total 30-day complication rate likely due to the increased complexity of the procedure, longer operative times on average, and longer hospital stays. The higher rate of transfusion associated with free flap procedures is likely related to the longer length of operative time required for free flap reconstruction and often larger surface area of injury. Transfusion has been previously shown not to be predictive of flap failure, suggesting free flaps should still be chosen over pedicled flaps if there is promise of greater restoration of form and function.[28] Free flaps were also associated with a greater rate of reoperation, likely due to operations requiring revision of the anastomosis or evacuation of hematoma. This should not deter surgeons from choosing these often superior reconstructive options but should encourage surgeons to practice careful preoperative planning and judicious intraoperative decision-making.

As a retrospectively designed study, we are limited in our ability to make direct correlations between these risk factors and the complications of upper extremity flap reconstruction. NSQIP has gone through many refinements to become the thorough and validated dataset that it is, but we may still be missing variables that could confound our findings. First, we may not be capturing all complications, particularly those beyond the 30-day postoperative period captured by NSQIP. The inability to extract information regarding a patient's time from injury to their reconstruction is another limitation inherent to NSQIP. Time of reconstruction is a subject that has been debated since the late 1980s and largely driven by the findings of Godina, which support early definitive reconstruction.[29] The 72 hours to reconstruction those authors put forth have been brought into question over the last decade, with other authors detailing that the reconstructive window can be extended past 72 hours.[30,31]The advent and implementation of vacuum-assisted closure therapy for wound management, for example, have been cited as one of the drivers to these recent findings; this is another intervention that would be difficult to accurately extract from NSQIP database.[32]

Lee et al discussed the effect of a surgeon's experience with extremity reconstruction, referencing his own findings and Godina's earlier work as examples. Godina's findings were limited by not controlling for his learning curve, exemplified by the 26 and 4% complication rates in his first and last 100 reconstructions, respectively. Lee et al found that flaps performed during his first era (1976–1996) were associated with higher rates of major complications when compared with the later era (1997–2016); this remained statistically significant on multivariate analysis as well.[30] In our present analysis, we were limited by the inability to extract and thus control for the experience a surgeon will gain over time, which could translate to differences in postoperative outcomes. However, we were able to assess trends in the complication rates over the study period, and we did not observe a difference in complication rates based on the year of reconstruction. We did reveal a significant association between lower overall complication rates and reconstructions performed by plastic surgeons. Therefore, the specialty of the reconstructive surgeon may serve as a better surrogate for surgeon experience if the assumption is made that plastic surgeons will have more experience with flap reconstructions than other specialties. Furthermore, the database limits our ability to identify and in turn differentiate complications based on the specific flap used in reconstruction. There is a need for future prospectively designed studies to compare complications in upper extremity reconstruction in certain patient groups and for specific flap types.

As flap reconstruction in upper extremity defects becomes more common with improvements in surgical technique,

understanding patient and surgical factors that could contribute to complications is of the utmost importance. This study provides some guidance in preparing for the complexities of upper extremity reconstruction. Careful planning is needed for patients with ASA classification >2, preoperative anemia, preoperative steroid use, bleeding disorders, and contaminated wounds. Male patients may require more thorough counseling in activity restriction following reconstruction. Free flaps may provide a better chance for restoration of form and function in certain defects. These more complex operations should be carefully planned and should be performed by the most experienced and skilled reconstructive surgeons to reduce operative time and chance of reoperation.

Conflict of Interest

None declared.

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