**Introduction:** While there is extensive literature investigating surgical outcomes in free flaps for adults, there is a dearth of information on the efficacy of flap use in the pediatric population. This study is the first to measure complication rates following pediatric free flap reconstruction on a national level.

**Methods:** All pediatric free flap cases between 2012 and 2018 were identified and stratified by type of flap using current procedural terminology codes assigned to the primary procedure in the National Surgical Quality Improvement Program database. Each entry included the recipient location of the flap, postoperative complications, and demographics. Chi-square analysis was used to compare complication rates across various flap groupings. In addition, univariate and multivariate analyses were used to identify independent predictors of flap complications or failure.

**Results:** Multivariate regression analysis demonstrated that compared to bone flaps, there is increased risk of nonbleeding complications in skin (Odds Ratio (OR) = 7.7, \( P = 0.029 \)), muscle (OR = 10.6, \( P = 0.012 \)), and osteocutaneous flaps (OR = 10.8, \( P = 0.018 \)). Flap of the trunk (OR = 40.9, \( P = 0.003 \)) and upper extremities (OR = 32.9, \( P = 0.041 \)) had a higher odds of bleeding complications compared to head-and-neck flaps. Regression analysis also showed that older age is associated with bleeding complications, with patients aged 5–11 years (OR = 38.5, \( P = 0.027 \)) and 12–17 years (OR = 30.6, \( P = 0.038 \)) having greater rates compared to patients under the age of 2. The pediatric flap reoperation rate was found to be 3.6%–4.7%, with the highest flap anastomotic complication rate in the head-and-neck region (6.9%–8.0%).

**Conclusion:** Free flap reconstruction across flap type, anatomic location, and age ranges are safe and efficacious in the pediatric population.

**Keywords:** Flap, free flap, pediatric, tissue transfer

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**Abstract**

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**Address for correspondence:** Dr. Michael Alperovich,
Department of Surgery, Yale School of Medicine, Section of Plastic Surgery, 330 Cedar Street, Boardman Building, 3rd Floor, New Haven, CT 06510, USA.
E-mail: michael.alperovich@yale.edu
wound healing. While the handful of previous case series have reported outcomes comparable to adult populations, there remains little consensus on the safety of free flaps in the pediatric population. Flap failure following pediatric microvascular reconstruction has ranged from 0% to 12%, and rates of minor complications have been reported to be as low as 9% and as high as 67%.[10,12-15] The majority of these studies have been single-surgeon case reports or single-institution cohort studies.

Given the inconsistency in reported complication rates and the paucity of multisurgeon and/or broader analyses, this study sought to measure complication rates following pediatric free flap reconstruction across a national database.

**METHODS**

**The database**

The National Surgical Quality Improvement Program (NSQIP) is a well-known multi-institutional database provided by the American College of Surgeons (ACS). Through a collaboration with the American Pediatric Surgical Association, the ACS developed a database specifically for pediatric patients with slightly modified variables to account for the risk factors and complications relevant to pediatric patients. The database aims to provide and improve upon the quality of care delivered to younger patients.[16]

**Patient and variable identification**

All cases of pediatric free flaps were collected from the 2012–2018 NSQIP Pediatric database using the following current procedural terminology (CPT) codes: 15756, 15757, 15758, 20955, 20956, 20957, 20962, 20969, 20970, 20972, and 20973. All CPTs assigned to the primary procedure, either by the primary or secondary surgical teams, were assessed for inclusion. The type of flap was identified using CPT codes. The recipient location of the flap was assessed by the CPT codes as part of the concurrent procedure. Demographics of the patients, including sex, age, race, height, weight, American Society for Anesthesiologists Physical Status (ASA-PS) classification, and medical comorbidities, were collected. Overweight and obese status were assigned using the calculated body mass index, age, and sex for all patients 2 years or older as per the Centers for Disease Control and Prevention guidelines.[17]

**Identification of postoperative complications and graft failure**

Complications within 30 days of surgery were identified, including unplanned return to the operating room (OR), unplanned readmission, surgical site infections, wound disruption, and numerous medical complications. Patients were assigned into groups based on whether they had a postoperative bleeding complication or required a blood transfusion within 72 h of surgery. In addition, patients were assessed for whether there was a nonbleeding-related postoperative complication. As the database does not have a category for flap failure, unplanned reoperations were tracked. Assigned CPT and ICD-9 or ICD-10-CM codes of the unplanned reoperation were used to determine the reason for the return to the OR.

**Statistical analysis**

The rates of complications were compared across age groupings, flap location, and flap type by Chi-squared analysis. Differences in demographic and flap characteristics were compared between the aforementioned groups by Chi-squared analysis. Univariate and multivariable analyses were used to identify demographic and flap variables associated with bleeding or nonbleeding complications. Multivariable analyses were controlled for all variables significant on univariate analysis. Statistical significance was assigned a threshold of $P < 0.05$. SPSS version 24.0 (Armonk, NY, USA: IBM Corporation) was used to conduct the statistical analysis.

**RESULTS**

**Patient and flap characteristics**

In total, 192 pediatric patients underwent a free flap during the study period. Mean age was 10.2, with a standard deviation of 4.8. The patients were primarily male (51.0%), white (76.7%), and not overweight (67.9%). The majority of flaps were bone (59.4%) while the others were cutaneous (10.9%), myofascial (14.6%), fascial (4.7%), osteocutaneous (8.3%), or mixed in composition (2.1%). Many of the flaps were in the head-and-neck region (47.5%), with the remaining flaps in the trunk (20.8%), lower extremities (29.5%), or upper extremities (2.2%).

**Rates of complications**

Of these 192 patients, 68 (35.4%) had at least one postoperative complication, with 58 (30.2%) suffering a bleeding complication and 17 (8.9%) with a nonbleeding complication. There was no significant difference between patients with or without a bleeding complication regarding patient age or flap type. Flaps of the trunk had higher rates of bleeding complications than the other locations ($P < 0.001$). Alternatively, there was no significant difference among patients who experienced a nonbleeding complication across age or flap location groups. However, nonbleeding complications were
more common in skin, muscle, and osteocutaneous flaps ($P < 0.001$) [Figure 1]. There were no mortalities within 30 days of surgery.

**Rate of flap failure**
A total of 11 (5.7%) of patients had an unplanned reoperation. Two of these reoperations were not related to the flap, seven were related to the flap, and two had an unknown indication. This leaves an estimated overall amount of flap failures or salvage at 7–9, at an overall rate of 3.6–4.7%. The highest flap anastomotic complication rate was observed in the head and neck with an estimated 6.9%–8.0% anastomotic complication rate. The trunk region had had 0–1 failures for a 0.0%–2.6% complication rate, and the lower extremity had 1 failure out of 54 cases (1.9%). There were no anastomotic complications in the upper extremity [Table 1]. There were no significant differences in anastomotic complication rate by flap location.

**Comparison of patient and flap characteristics**
Patients with a postoperative bleeding complication were less likely to be white ($P = 0.016$), and more likely to have a higher ASA-PS classification ($P < 0.001$), one of numerous medical comorbidities ($P < 0.05$), or receive a flap in the trunk region ($P < 0.001$). Patients who experienced a nonbleeding complication in the postoperative period were more likely to be male ($P = 0.001$), have comorbidities ($P < 0.05$), or receive skin, muscle, or osteocutaneous flaps ($P < 0.001$) [Tables 2 and 3].

**Predictors of complications**
On multivariable regression adjusted for chronic comorbidities, older age was associated with bleeding complications, with patients aged 5–11 years (OR = 38.5, $P = 0.027$) and 12–17 years (OR = 30.6, $P = 0.038$), demonstrating greater odds risk for complications relative to patients <2 years old. Further, patients having a flap of the trunk (OR = 40.9, $P = 0.003$) and upper extremities (OR = 32.9, $P = 0.041$) had a higher odds of bleeding complications compared to head-and-neck flaps.

On multivariable regression for nonbleeding complications, male patients had a higher odds risk for complications than females (OR = 14.4, $P = 0.014$). Furthermore, as compared to bone flaps, a higher odds ratio of nonbleeding complications was seen in skin (OR = 7.7, $P = 0.029$), muscle (OR = 10.6, $P = 0.012$), and osteocutaneous flaps (OR = 10.8, $P = 0.018$) [Table 4].

**DISCUSSION**
Advancements in microsurgical technique and success rates have expanded the clinical application of free flaps with extended indications. Historically, hesitancy to perform free flaps in the pediatric population was related to small vessel diameter, concern for vessel size mismatch and spasms, and morbidity of the donor and recipient site in a growing patient.[18-20] However, in recent years, there has been a growing body of single-institution studies supporting the safety and efficacy of pediatric microvascular surgery. This paper is the first national cohort analysis of free flap complications in the pediatric population published to date, with 192 pediatric patients who underwent free flaps across a diverse array of indications.

**Table 1: Details on unplanned reoperations following pediatric free flaps**

| Reoperation | Flap type     | Flap location | Flap revision? |
|-------------|---------------|---------------|----------------|
| 1           | Skin          | Trunk         | Unknown        |
| 2           | Bone          | Lower extremity | Yes           |
| 3           | Osteocutaneous| Head and neck | Yes           |
| 4           | Osteocutaneous| Head and neck | Yes           |
| 5           | Skin          | Head and neck | Yes           |
| 6           | Muscle        | Lower extremity | No            |
| 7           | Muscle        | Head and neck | Yes           |
| 8           | Skin          | Head and neck | Unknown       |
| 9           | Muscle        | Head and neck | Yes           |
| 10          | Osteocutaneous| Head and neck | Yes           |
| 11          | Skin          | Lower extremity | No            |

**Figure 1:** Complication rates following pediatric free flaps by (a) recipient site and (b) graft type. **$P < 0.001$**
The most common type of free flap was bone, which is consistent with the most common type of solid tumors in the pediatric population.[21,22] The majority of microvascular reconstructions were in the head and neck, and only a small minority of free flaps were performed in individuals under the age of 5 [Tables 2 and 3].

When examining the safety profile of free flaps, nonbleeding complications occurred in 8.9% of patients. The most significant predictor of nonbleeding complications was free flap composition, with skin, muscle, and osteocutaneous flaps having a higher risk than bone and fascial flaps [Table 4]. Primarily driving the higher complication rates were unplanned readmissions and reoperations. Potentially, the higher vascular demands of composite flaps increase the risk of ischemia, congestion, and flap failure.

Bleeding or the perioperative transfusions were the most common perioperative event, occurring in about...
### Table 3: Comparison of flap characteristics between patients who did or did not experience postoperative complications

|                       | Total Cohort (n=192) | No bleeding or transfusion (n=134, 69.8%) | Bleeding or transfusion (n=58, 30.2%) | P   | No nonbleeding complication (n=175, 91.1%) | Any nonbleeding complication (n=17, 8.9%) | P   |
|-----------------------|----------------------|-----------------------------------------|-------------------------------------|-----|------------------------------------------|------------------------------------------|-----|
| **Number of flaps**   |                      |                                         |                                     |     |                                          |                                          |     |
| One                   | 183 (95.3)           | 129 (96.3)                              | 54 (93.1)                           | 0.341 | 166 (94.9)                              | 17 (100.0)                              | 0.338 |
| Two or more           | 9 (4.7)              | 5 (3.7)                                 | 4 (6.9)                             |       | 9 (5.1)                                 |                                          |     |
| **Flap type**         |                      |                                         |                                     |     |                                          |                                          |     |
| Bone                  | 114 (59.4)           | 81 (60.4)                               | 33 (56.9)                           | 0.508 | 112 (64.0)                              | 2 (11.8)                                | <0.001 |
| Skin                  | 21 (10.9)            | 16 (11.9)                               | 5 (8.6)                             |       | 16 (9.1)                                | 5 (29.4)                                |     |
| Muscle                | 28 (14.6)            | 17 (12.7)                               | 11 (19.0)                           |       | 21 (12.0)                               | 7 (41.2)                                |     |
| Fascial               | 9 (4.7)              | 8 (6.0)                                 | 1 (1.7)                             |       | 9 (5.1)                                 | 0                                        |     |
| Osteocutaneous        | 16 (8.3)             | 10 (7.5)                                | 6 (10.3)                            |       | 13 (7.4)                                | 3 (17.6)                                |     |
| Mixed                 | 4 (2.1)              | 2 (1.5)                                 | 2 (3.4)                             |       | 4 (2.3)                                 | 0                                        |     |
| **Flap location*      |                      |                                         |                                     |     |                                          |                                          |     |
| Head and neck         | 87 (47.5)            | 68 (54.4)                               | 19 (32.8)                           | <0.001 | 74 (44.6)                              | 13 (76.5)                               | 0.086 |
| Trunk                 | 38 (20.8)            | 13 (10.4)                               | 25 (43.1)                           |       | 37 (22.3)                               | 1 (5.9)                                 |     |
| Upper extremity       | 4 (2.2)              | 3 (2.4)                                 | 1 (1.7)                             |       | 4 (2.4)                                 | 0                                        |     |
| Lower extremity       | 54 (29.5)            | 41 (32.8)                               | 13 (22.4)                           |       | 51 (30.7)                               | 3 (17.6)                                |     |

*Unknowns excluded

### Table 4: Multivariable analyses assessing the relationship between demographic and flap characteristics and postoperative complications

|                                | Bleeding or transfusion within 72 h of surgery | Any nonbleeding complication |
|--------------------------------|-----------------------------------------------|------------------------------|
|                                | aOR | 95% CI         | P   | aOR | 95% CI         | P   |
| Male sex                       |     |                |     |     |                |     |
| Age (years)                    |     |                |     |     |                |     |
| <2                             | 1.00 | 0.00-19.99     | 0.999| 1.00 | 0.01-19.99     | 0.999|
| 2-4                            | 0.00 | 0.00-19.99     | 0.999| 1.00 | 0.01-19.99     | 0.999|
| 5-11                           | 1.51 | 1.01-2.26      | 0.027| 1.51 | 1.01-2.26      | 0.027|
| 12-17                          | 1.21 | 0.77-1.90      | 0.38 | 1.21 | 0.77-1.90      | 0.38 |
| Race                           |     |                |     |     |                |     |
| White                          | 1.00 | 0.00-19.99     | 0.999| 1.00 | 0.01-19.99     | 0.999|
| Black                          | 3.58 | 0.36-35.29     | 0.275| 3.58 | 0.36-35.29     | 0.275|
| Other                          | 2.67 | 0.35-20.20     | 0.342| 2.67 | 0.35-20.20     | 0.342|
| ASA                            |     |                |     |     |                |     |
| PS1                            | 1.00 | 0.00-19.99     | 0.999| 1.00 | 0.01-19.99     | 0.999|
| PS2                            | 0.54 | 0.13-2.34      | 0.656| 0.54 | 0.13-2.34      | 0.656|
| PS3 or greater                 | 3.13 | 1.23-8.26      | 0.391| 3.13 | 1.23-8.26      | 0.391|
| Flap type                      |     |                |     |     |                |     |
| Bone                           | 7.66 | 1.23-47.40     | 0.029| 7.66 | 1.23-47.40     | 0.029|
| Skin                           | 10.59 | 1.68-66.86    | 0.012| 10.59 | 1.68-66.86    | 0.012|
| Muscle                         | 0.00 | 0.00-19.99     | 0.999| 0.00 | 0.00-19.99     | 0.999|
| Fascial                        | 10.76 | 1.51-76.51    | 0.018| 10.76 | 1.51-76.51    | 0.018|
| Osteocutaneous                 | 0.00 | 0.00-19.99     | 0.999| 0.00 | 0.00-19.99     | 0.999|
| Mixed                          | 40.87 | 2.97-562.54  | 0.006| 40.87 | 2.97-562.54  | 0.006|
| Flap location*                 |     |                |     |     |                |     |
| Head and neck                  | 40.87 | 2.97-562.54  | 0.006| 40.87 | 2.97-562.54  | 0.006|
| Trunk                          | 32.88 | 1.15-943.87  | 0.041| 32.88 | 1.15-943.87  | 0.041|
| Upper extremity                | 1.30  | 0.18-9.37     | 0.906| 1.30  | 0.18-9.37     | 0.906|
| Lower extremity                | 1.30  | 0.18-9.37     | 0.906| 1.30  | 0.18-9.37     | 0.906|

aOR reflects odds of complication as compared to the reference variable adjusted for demographics and comorbidities significantly different on univariate analysis. BMI category, inpatient status, and the number of flaps are all insignificant for both univariates and not shown. Only comorbidities significant on one of the univariate analyses shown. aOR – Adjusted odds ratio, BMI – Body mass index, ASA – American Society of Anesthesiologists, CI – Confidence interval.
one-quarter patients, which is unsurprising given the routine perioperative use of blood products in pediatric patients.[18] Blood transfusion has inherent metabolic and infectious risks.[21,24] Free flap reconstruction of the trunk had higher transfusion rates, which may be related to the large volume of blood loss during spinal surgeries and longer operative times. Interestingly, younger age was associated with less frequent bleeding or transfusion rates, supporting the safety of free flap reconstruction in the youngest cohorts.

While other studies have assessed complication profiles in either lower extremity or head-and-neck reconstruction, this is the first to evaluate surgical outcomes across all free flaps in the pediatric population. When excluding blood transfusions from the complication profile, <10% of free flap reconstructions resulted in complications and about 6% necessitated a return to the OR. Of those requiring reoperation between 7 and 9 were related to anastomotic complications – primarily in the head-and-neck flaps. Consistent with the adult population, the highest rate of flap failure was in the head-and-neck region.[25] Although trunk free flaps have higher bleeding complications, it does not impact flap survival.

Given the low complication and failure rates, our data support an acceptable safety profile and success rate for free flap reconstruction in pediatric patients. Overall, free flap success is likely attributable to a low prevalence of comorbidities, nonatherosclerotic vessels, and large vessel size to flap volume ratio in this population.[14] Based on our data, free flap tissue type is the primary predictor of complications while bleeding and transfusion is most closely associated with the trunk.

Limitations of this study include the retrospective nature of the NSQIP pediatric database, as well as the lack of operative notes and other details that may provide more granular detail regarding wound complications and flap failure. Further, the large confidence intervals in the multivariable regressions limit to use of specific odds ratios for interpretation.

**Conclusion**

Free flap reconstruction across flap type, anatomic location, and age ranges are both feasible and largely successful in the pediatric population. Our study illustrates that pediatric free flaps are safe and effective in the largest cohort studied to date. Paralleling the adult population, free flap failure rates are highest in head-and-neck reconstruction.

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**Conflicts of interest**

There are no conflicts of interest.

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