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Blood Transfusion Incidence, Risk Factors, and Associated Complications in Surgical Treatment of Hip Dysplasia

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Abstract

Background—Perioperative bleeding requiring blood transfusion is a known complication of hip dysplasia (HD) surgery. Here we examine rates of, risk factors for, and postoperative complications associated with transfusion during HD surgery.

Methods—The National Surgical Quality Improvement Program (NSQIP) Pediatric database was queried for patients treated by an orthopedist from 2012-2013. HD cases were categorized by Current Procedural Terminology codes into femoral osteotomies, acetabular osteotomies, combined femoral/acetabular osteotomies, and open reductions. Patients were grouped by comorbidities: neuromuscular (NM) disease (e.g., Cerebral Palsy) group, non-NM with other comorbidity (Other) group, and no known comorbidity (NL) group. Patients were stratified by weight-normalized transfusion volume. Multivariate regression analysis of transfusion association with procedures, demographics, comorbidities, preoperative laboratory values, and 30-day complications was performed.

Results—A total of 1,184 HD cases were included. Transfusion rates for the NL, Other, and NM groups, respectively, were: 44/451 (9.8%), 61/216 (28.2%), and 161/517 (31.1%). Transfusion volumes (mean±SD) for the NL, Other, and NM groups, respectively, were: 8.4±5.4 mL/kg, 13.9±8.8 mL/kg, and 15.5±10.0 mL/kg ($p<0.001$). Combined osteotomies had the highest transfusion rates in the NM and Other groups (35.7% and 45.8%, respectively), whereas acetabular osteotomies had the highest rate in the NL group (15.8%). Open reductions had the lowest transfusion rate (all groups). Longer operations were independently associated with transfusion (all groups, per hour increase, $OR>1.5$, $p<0.001$). Independent patient risk factors included preoperative hematocrit $<31\%$ (NM group, $OR=18.42$, $p=0.013$), female gender (NL group, $OR=3.55$, $p=0.008$), developmental delay (NM group, $OR=2.37$, $p=0.004$), pulmonary comorbidity (NM group, $OR=1.73$, $p=0.032$), and older age (NL group, per year increase: $OR=1.29$, $p<0.001$). In all groups, transfusion was associated with longer hospitalization

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($p < 0.001$). We observed a volume-dependent increase in overall complication rate within the Other group for transfusion volumes > 15 mL/kg (25.0% vs. 5.4% for < 15 mL/kg, $p = 0.048$).

Conclusion—We identified several risk factors for transfusion in HD surgery. The incidence of transfusion in HD surgery and its association with adverse outcomes warrants development of appropriate patient management guidelines.

Level of Evidence—Prognostic Level III

Keywords

dysplasia; HD; blood transfusion; pediatric; orthopaedic; NSQIP

Introduction

Hip Dysplasia (HD) is the most prevalent pediatric hip disorder with an incidence between 1 and 25 per 1,000 births.¹⁻⁶ Although conservative treatment of HD is most common, surgical treatment of HD is indicated when conservative treatment fails or dysplasia persists.⁵⁻⁷ Procedures performed include closed or open reduction and femoral and/or acetabular osteotomy.⁵⁻¹¹

Complications such as AVN and infection have been studied extensively in HD surgery.^{5,12} Severity of HD, obesity, bilateral disease, patient age, presence of neuromuscular disease, and type of procedure performed have been shown to increase complication rates.^{7-9,11} However, risk factors for and rates of blood transfusion in pediatric HD procedures have not been extensively studied. To our knowledge, the only previous study investigating blood transfusion incidence and associated outcomes in pediatric hip surgery found that single stage HD osteotomy resulted in lower required blood transfusion volume (200 ± 20 vs. 425 ± 22 mL), lower hospital costs, lower AVN rate, and shorter length of stay (5.5 ± 1.5 vs. 11.5 ± 1.3 days) compared to patients receiving consecutive, multiple-stage HD osteotomies.¹³

Blood transfusions are associated with longer length of stay, higher hospital costs and 1% risk of transfusion related complication in general pediatric admissions¹⁴ and with longer length of stay and higher mortality in pediatric trauma patients.¹⁵ Transfusion in pediatric spine surgery has been associated with higher overall complication rate and pulmonary complications.¹⁶ Older age, male gender, race, weight loss, anemia, combined anterior/posterior approach, and higher number of fused levels increased the risk of receiving a transfusion.¹⁷ Minhas et al (2015) studied transfusion volume and its associations with adverse outcomes in pediatric spine surgery; the study found that transfusion volume greater than or equal to 20 mL/kg was the minimum volume independently associated with increased total complication rate with a complication rate of 5.9 percent.¹⁸ Interestingly, very few other studies have looked at transfusion volume (or weight-normalized transfusion volume) as a risk factor for complications.

To our knowledge, no previous study has specifically investigated blood transfusion rates, risk factors, or associated adverse outcomes in pediatric HD surgery. The purpose of the current study is to examine the incidence of, risk factors for, and adverse outcomes

associated with receiving a blood transfusion during osteotomy or open reduction for pediatric HD treatment using a nationally representative clinical database.

Methods

Data Acquisition

The American College of Surgeons National Surgical Quality Improvement Program, Pediatric (ACS NSQIP Pediatric) is a pediatric surgical database containing prospectively collected case information from over 50 participating institutions.¹⁹ The database includes 129 Health Insurance Portability and Accountability Act–compliant variables; these include patient demographics, Current Procedural Terminology (CPT) procedure code, preoperative laboratory values, comorbidities, primary ICD-9 diagnoses, peri- and postoperative complications, reoperations, readmissions, and mortality.¹⁹ The ACS NSQIP trains data abstractors and nurses at each participating institution to ensure data integrity. NSQIP data are consistent, with inter-rater discrepancy rates of less than 2%.¹⁹ Previous studies comparing the NSQIP to other patient databases have shown that the NSQIP provides more accurate mortality and complication data than other administrative databases, readmission data is highly consistent with hospital medical and administrative records, and hospitals who use NSQIP are more likely to achieve better quality outcomes and lower costs.²⁰⁻²³ The NSQIP contacts patients post-discharge by telephone or letter to collect follow-up data; a minimum of 80% follow-up is required.¹⁹ The institutional review board (IRB) of the authors' institution does not require study approval for ACS NSQIP Pediatric data analysis since all information is de-identified and HIPAA-compliant.

Patient Cohort Selection

Data from the 2012 and 2013 pediatric NSQIP database were included for analysis. Patients were included only if they are less than 18 years old at the time of index procedure. Pediatric orthopaedic HD cases were categorized by CPT codes into femoral osteotomies, acetabular osteotomies, combined femoral/acetabular osteotomies, and open reductions. The following CPT codes were included for analysis: 27140, 27146, 27147, 27151, 27156, 27165, 27258, and 27259. Patients were further grouped into patients receiving one or more perioperative blood transfusions and patients who did not receive a transfusion. Patients with neuromuscular (NM) disorder diagnoses (cerebral palsy, quadriplegia, diplegia, hemiplegia, etc.) were filtered from the general HD cohort and grouped together. Patients with other non-NM comorbidities were filtered from the remaining cohort and grouped together (Other group). Finally, patients without any known comorbidity were grouped together (NL group).

Patient demographics included age, gender, race, and ASA classification. Comorbidities included pulmonary, gastrointestinal, renal, central nervous system, cardiac, cerebral palsy or other neuromuscular disorder, steroid use, need for nutritional support, bleeding disorder, hematologic disorder, and pharmacologic inotropic support at time of surgery (detailed list of conditions included within categorical comorbidity variables displayed in Supplement S1). Preoperative laboratory values included serum albumin, sodium, hematocrit, white blood cell (WBC) count, platelet count, partial thromboplastin time (PTT), and prothrombin time (PT). Abnormal preoperative lab values were set by predetermined pediatric lab

reference ranges. Patient outcomes included total length of hospital stay, length of operation, nerve injury, acute renal failure (ARF), renal insufficiency, wound dehiscence, unplanned reintubation, cerebrovascular accident (CVA), infection (including superficial SSI [surgical site infection], deep SSI, organ/space SSI, sepsis, pneumonia, urinary tract infection, and central line associated bloodstream infection), occurrence of any adverse event (AAE), readmission, and reoperation. All diagnostic criteria were coded using ICD-9 codes.

Transfusion volume was normalized by patient weight and was included in the analysis to determine if outcomes were influenced by transfusion volume as opposed to simply occurrence of transfusion. In order for a transfusion to be included in the NSQIP database, it must have been administered within 72 hours of the beginning of the procedure and does not include fresh frozen plasma, platelets, cryoprecipitate, or albumin transfusions. NSQIP includes cell-saver/intraoperative blood salvage devices as part of the total volume of blood products transfused; however, the database does not include categorical variables to ascertain whether such devices were used or to differentiate such salvaged blood transfusions from other blood transfusions.

Statistical Analysis

Bivariate analysis of blood transfusion outcome association with procedure type, patient demographics, comorbidities, preoperative lab values and 30-day complications was performed using Fisher's exact test and independent sample t-test where appropriate. One-way ANOVA was performed to compare transfusion volumes between groups. Factors with significance of $p < 0.20$ in the bivariate analysis were then analyzed in a multivariate analysis via binary logistic regression and were considered independently significant when $p < 0.05$. Receiver operating characteristic (ROC) curve analysis was performed to determine predictive accuracy of the logistic regression models by calculating area under the ROC curve. All statistical analyses were performed using SPSS version 22.0 (SPSS Inc., Chicago, IL).

Results

A total of 1,184 cases met the inclusion criteria. Patient groups were sorted as follows: 451 patients in with NL group, 216 patients in the Other group, and 517 patients within the NM group. Transfusion rates for the NL, Other, and NM groups, respectively, were: 9.8%, 28.2%, and 31.1%. In order of decreasing frequency, procedures included acetabular osteotomies (31.8%), femoral osteotomies (27.4%), open reduction (23.4%), and combined femoral/acetabular osteotomies (17.4%). Combined osteotomies had the highest transfusion rates in the NM and Other groups (35.7% and 45.8%, respectively), whereas acetabular osteotomies had the highest rate in the NL group (15.8%). Open reductions had the lowest transfusion rate among all groups. On average, transfused patients were significantly older than non-transfused patients within the NL and Other groups. Females were more likely to require a transfusion in the NL group. Black race was slightly protective against need for transfusion within the NL and Other groups, whereas Asian race was slightly protective in the NM group. Operative time was significantly longer for transfused patients in all groups. Univariate analysis of patient demographics and procedures is displayed in Table 1.

In the Other group, comorbidities associated with increased risk of transfusion included seizure disorders, bleeding disorders, and an ASA Score 3. In the NM group, comorbidities associated with transfusion included pulmonary comorbidity, GI comorbidity, cardiac comorbidity, developmental delay/impaired cognitive status, seizure disorder, nutritional support, inotrope use during surgery, ASA Score 3, and structural CNS abnormality. Most comorbidities were excluded from the NL group. Univariate analysis of patient comorbidities is displayed in Table 2.

Patient preoperative laboratory values are displayed in Table 3. In the NL group, only thrombocytopenia was associated with transfusion. In the Other group, abnormal PTT was associated with transfusion. In the NM group, hyponatremia, anemia, thrombocytopenia, and abnormal PT were associated with transfusion. No differences were seen for hypoalbuminemia or elevated WBC count within any group.

Independent risk factors for requiring a transfusion in the NL group as determined by multivariate analysis included acetabular osteotomy, female gender, longer operative time, and older patient age. Independent risk factors in the Other group included acetabular osteotomy, combined acetabular/femoral osteotomy, and longer operative time. Finally, independent risk factors for transfusion in the NM group included anemia (preoperative hematocrit < 31%), developmental delay, pulmonary comorbidity, and longer operative time. Results of the multivariate logistic regression analysis are shown in Table 4.

ROC curve analysis for the NM group logistic regression model yielded an area under the curve (AUC) of 0.774 (95% CI = 0.731-0.816, $p < 0.001$). For the Other group, ROC curve analysis generated an AUC of 0.814 (95% CI = 0.756-0.871, $p < 0.001$). For the NL group, ROC curve analysis AUC was 0.903 (95% CI = 0.854-0.952, $p < 0.001$). The reported p-values are with respect to the null hypothesis that the logistic regression models did not predict transfusion outcome better than chance alone.

Associated adverse outcomes with receiving a transfusion included longer length of stay in all three groups ($p < 0.001$ for all; mean length of stay was at least one day greater than non-transfused group for all groups). No difference was seen in nerve injury, renal insufficiency, wound dehiscence, CVA, superficial SSI, deep SSI, organ/space SSI, or sepsis outcomes for any group. Readmission and reoperation outcomes were not significantly different in any group. In the NM group, length of stay and any adverse event were the only outcomes significantly associated with transfusion, although unplanned reintubation and UTI showed a trend towards significant association. In the NL group, length of stay was the only outcome that was significantly different between transfused and non-transfused patients. In the Other group, length of stay, unplanned intubation, pneumonia, and rate of any adverse event were all significantly different between transfused and non-transfused patients. Adverse outcomes are shown in Table 5.

Mean transfusion volumes for each study group are displayed in Figure 1a. Mean weight-normalized transfusion volumes for each study group may be seen in Figure 1b. No significant difference was found between groups regarding absolute transfusion volume; however, significant differences were seen between groups for weight-normalized

transfusion volumes. Transfusion volume-associated outcomes are shown in Table 6. Results for patients receiving a transfusion volume > 15 mL/kg are similar for results previously reported for the transfusion group in Table 5; however, important differences seen when accounting for normalized volume include higher rates of any adverse event within the Other group. Rates of superficial SSI were higher, though not significantly, in the NM group receiving a transfusion > 15 mL/kg. Wound dehiscence was more frequent in the Other group receiving a transfusion > 15 mL/kg, though this difference was not significant.

Discussion

Blood transfusion in pediatric surgery is not entirely benign, with previous studies showing significant adverse outcomes associated with receiving a transfusion peri- or postoperatively.¹⁴⁻¹⁸ In the present study, the incidence of transfusion was relatively high – 22.% overall. We identified risk factors for transfusion that were not surprising, but did differ slightly between the groups. Predictably, longer operative time was an independent risk factor for transfusion in all groups. Independent patient risk factors for requiring a transfusion included older age and female gender (NL group). Patient comorbidities independently associated with transfusion included anemia, impaired cognitive status/developmental delay, and pulmonary comorbidity (NM group). Adverse outcomes associated with receiving a transfusion included longer length of stay, unplanned reintubation (Other group), pneumonia (Other group), and any adverse event (Other and NM groups). Transfusion volume >15 mL/kg was associated with longer length of stay, higher rate of pneumonia, and higher rate of any adverse event.

The rate of transfusion in this study was substantial (22.5% overall) and a moderate number of patients required large volume transfusions (29.5% of patients transfused received > 15mL/kg). For comparison, incidence of transfusion in pediatric scoliosis surgery has been previously reported to be 18-67%;¹⁶⁻¹⁸ however, the lower incidences of 18% and 30% were gathered from an administrative inpatient database (i.e., the Nationwide Inpatient Sample), whereas the incidence of 67% was gathered from the NSQIP Pediatric database. Previous studies have shown that NM disease increases the risk of requiring a transfusion and sustaining transfusion-related complications, which is consistent with our findings.¹⁴ A previous study on transfusion in adult acetabular osteotomies reported transfusion incidence of 20%, which is similar to the incidence reported here in pediatric HD surgery.²⁴ Transfusion incidence in previous studies on adult total hip arthroplasty has ranged from 12% to 27%.²⁵⁻²⁸

Operative factors were major determinants of need for transfusion. Longer operative time was an independent risk factor for transfusion in all groups. Those receiving a transfusion > 15 mL/kg spent, on average, over two hours longer in the operating room than those not receiving a transfusion. Additionally, when controlling for operative time, procedure type was significantly associated with transfusion; acetabular osteotomies and combined femoral/acetabular osteotomies were independently and significantly associated with transfusion. These findings indicate that in many cases for HD patients, the operative factors are major determinants of need for transfusion. This is not surprising since longer operative time allows more opportunity for exposed surfaces to bleed and added acetabular procedures

expose larger volumes of well perfused cancellous bone. Furthermore, previous studies have found a correlation between increased length of operation and transfusion.¹⁸ Patient factors also play a role, as age, gender, pre-existing comorbidities and abnormal lab values were identified as an independent risk factor for transfusion in certain groups as well. The NL group, which had comorbidities excluded, had a substantially lower rate of transfusion compared to the other two groups, indicating that comorbidities play an important role in need for transfusion.

In the NM group, patient related factors played a larger role in need for transfusion. Over two thirds were ASA 3, and in the transfusion group, there were significantly higher rates of pulmonary, GI and CNS comorbidities, as well as abnormal lab values including anemia, hyponatremia, thrombocytopenia and abnormal PT. Anemia and pulmonary comorbidities were independent risk factors, consistent with previous studies.¹⁴⁻¹⁸ CNS comorbidity/developmental delay was also an independent risk factor, which has not been previously reported. This may be reflective of more severe neuromuscular involvement and perhaps poorer general health and poor bone quality, which may increase the difficulty of the procedure. However, CNS comorbidity/developmental delay remained as an independent risk factor when controlling for operative time. With respect to surgical factors, the procedure performed was similar in the transfusion and non-transfusion groups, but total operative time was still an independent predictor of need for transfusion. Overall, the presence of noted comorbidities and abnormal lab values may help highlight the likely need for transfusion in this group.

For HD patients at risk for blood loss or need for transfusion (e.g., patients with risk factors identified above), it may be appropriate to consider antifibrinolytic therapies such as tranexamic acid (TXA) to reduce blood loss during pediatric HD surgery, especially in patients with aforementioned risk factors.^{29,30} Despite best efforts including risk stratification, transfusions will still be required for many patients. Therefore, it is important to highlight associated potential adverse outcomes. Transfusion was associated with longer length of stay, longer operative time, unplanned reintubation, pneumonia, and any adverse event. Some increase in length of stay with transfusion would be anticipated; however, the mean length of stay was over three days longer in transfused patients within the Other group and nearly two days longer in the NM group, a larger than expected effect. The longer length of stay may also be attributable to association with additional complications such as reintubation and pneumonia. Numerous studies have found significant correlation between length of stay and transfusion, both in the pediatric^{14,15,31} and adult population.^{13,25} In addition to higher costs of added stay, patients could also be exposed to more potential for hospital acquired conditions.

Unplanned reintubation was significantly higher in the group receiving any transfusion in the Other group and approached significance in the NM group. Unplanned intubation is a serious adverse outcome that can lead to additional complications and increased length of stay.³² The requirement for reintubation could be correlated with or explained by the higher incidence of pneumonia in the transfusion group. Furthermore, pre-existing comorbidities likely increase the need for re-intubation, which is supported by the observation that no reintubations occurred in the NL group.

One unexpected and novel finding was the increased incidence of pneumonia in transfused patients within the Other group. Previous studies have found increased risk of SSI, acute lung injury, and respiratory complications with transfusion, yet pneumonia has not specifically been linked to transfusion.³³ These observations may be explained by association with increased length of stay as a result of receiving a transfusion and by transfusion-related acute lung injury, which may increase the risk of pneumonia. Transfusion-related lung injury may occur by two mechanisms: volume-related lung damage and antibody-mediated lung damage.³³ Although we cannot definitively discern which mechanism is responsible for findings in this study, we did observe a higher rate of pneumonia in the group receiving a larger transfusion volume per body weight. Correlation-causation cannot be discerned by the results of this study, and caution should be taken when interpreting these findings.

Relevant negative findings in this study included a lack of significant association of transfusion with race, readmission, reoperation, and infection other than pneumonia and superficial SSI. Previous studies have found increased risk of transfusion in pediatric male spine patients,¹⁸ adult male THA patients,²⁶ and in adult female THA patients.^{25,27} Black race has previously been associated with increased risk of transfusion;^{11,25} however, in this study, there was actually a trend towards lower risk of transfusion for black patients. Previous studies have found increased risk of surgical site infection after transfusion in orthopedic surgery,^{27,33,35,36} including an increased risk of reoperation for infection after receiving transfusion preoperatively for adult THA.³⁴ In the current study, the only association of transfusion with SSI was an increased risk of superficial infection with large volume transfusion in the NM group; this association was not significant. The rarity of SSI in pediatric surgical populations likely limits the likelihood of finding any association.

Analysis of logistic regression model predictive power via ROC curve evaluation demonstrated acceptable predictive power for the NM group model (AUC>0.7) and good predictive power for the Other and NL group model (AUC>0.8). These results indicate that our logistic regression models were reasonably accurate at predicting transfusion outcome, especially in the Other and NL groups. The increased model accuracy within these groups can potentially be explained by the limitation of the categorical neuromuscular disease variable in a database like NSQIP, which does not allow further patient stratification or knowledge of disease severity.

This study has several limitations. Retrospective database studies are inherently limited by specific database parameters and sample bias or error. With regards to the NSQIP database, there are several nuances that limit the usefulness of its data, including level of detail of comorbidity data (especially for categorically coded comorbidities), lack of socioeconomic or geographical data, and lack of medication data.¹⁹ For this study, lack of more specific comorbidity data for pulmonary comorbidity and bleeding/hematologic disorders presents a problem for distinguishing which individual conditions might increase the risk for transfusion. Lack of data on patient medications that may contribute to or interfere with the need for transfusion (e.g., warfarin, vitamin K administration, etc.) presents a problem in interpreting our results in spite of this data. Additionally, NSQIP does not include specific procedural technique details (e.g., peri-acetabular vs. Dega acetabular osteotomy),

differentiate cell-saver devices from traditional transfusion, or identify specific laboratory values that trigger transfusion. The NSQIP Pediatric is a relatively new database, excluding the possibility of analyzing trends over time. Finally, care must be taken not to assume causation because of correlation between occurrence of a particular adverse outcome and transfusion.

Despite these limitations, this study may help guide surgeons and anesthesiologists in their care of pediatric patients during HD surgery. The relatively high incidence of transfusion in pediatric HD surgery warrants further study and guideline development for appropriate patient management. Important differences were observed between patients with NM disorders, who were found to have increased transfusion risk with certain comorbidities and abnormal preoperative laboratory values. Longer operative time is an important and independent risk factor for requiring a transfusion regardless of patient comorbidity grouping. Prophylactic antifibrinolytics such as TXA may be indicated for patients undergoing more complex procedures with anticipated longer operative times. Length of hospitalization was significantly longer for transfused patients and may contribute to higher costs and increased rate of hospital-acquired conditions. Patients receiving transfusion should be carefully monitored for post-operative complications, as we observed higher rates of adverse events in transfused patients; however, it is not clear whether the transfusions alone are responsible for higher complication rates.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. (A) Absolute transfusion volume (mean $\pm$ standard deviation) for each study group. (B) Body weight-normalized transfusion volume (mean $\pm$ standard deviation) for each study group. Statistical tests were performed using one-way ANOVA. NM = neuromuscular, NL = otherwise normal, Other = other non-NM comorbidity, NS = not significant.

Table 1

Patient demographics and operative variables associated with transfusion. Statistical analysis was performed using Fisher's exact test and independent sample t-test where appropriate. P values are with respect to the null hypothesis that there was no difference between transfused and non-transfused patients within (not between) each study group. Continuous variables are expressed as mean $\pm$ standard deviation.

Parameter	NL Group			Other Group			NM Group		
	Transfusion (n=44)	No transfusion (n=407)	P	Transfusion (n=61)	No transfusion (n=155)	P	Transfusion (n=161)	No transfusion (n=356)	P
Percent of total within group	9.8%	90.2%		28.2%	71.8%		31.1%	68.9%	
Age (years)	12.8 $\pm$ 4.5	6.6 $\pm$ 5.3	<0.001	9.4 $\pm$ 5.0	7.0 $\pm$ 5.2	0.002	9.3 $\pm$ 3.8	8.9 $\pm$ 3.9	0.259
Gender									
Male, %	22.7	36.4		42.6	39.4		59.6	57.3	
Female, %	77.3	63.6	0.095	57.4	60.6	0.758	40.4	42.7	0.632
Race									
White, %	81.8	73.7	0.279	75.4	72.9	0.864	67.1	65.7	0.841
Black, %	2.3	8.6	0.236	6.6	14.2	0.163	13.0	15.7	0.505
Asian, %	2.3	3.9	1.000	4.9	1.9	0.354	0.6	2.5	0.184
American Indian-Alaskan, %	0.0	0.5	1.000	0.0	0.0	-	0.0	0.3	1.000
Unknown, %	13.6	13.3	1.000	13.1	11.0	0.643	19.3	15.2	0.251
Acetabulum osteotomy, %	56.8	32.7	0.002	32.8	21.9	0.116	11.2	10.7	0.879
Femur osteotomy, %	20.5	27.5	0.373	19.7	32.3	0.069	34.2	41.0	0.145
Combined (Femur/Acetabular) osteotomy, %	13.6	12.5	0.812	44.3	20.6	0.001	50.9	41.6	0.056
Open reduction without osteotomy, %	9.1	27.3	0.006	3.3	25.2	<0.001	3.7	6.7	0.224
Operative time (minutes)	255.6 $\pm$ 97.1	160.0 $\pm$ 76.6	<0.001	268.2 $\pm$ 120.7	186.8 $\pm$ 83.4	<0.001	273.1 $\pm$ 93.7	204.4 $\pm$ 87.9	<0.001

NM = neuromuscular, NL = otherwise normal, Other = other non-NM disease comorbidity

Table 2

Patient comorbidities associated with transfusion. Statistical analysis was performed using Fisher's exact test. P values are with respect to the null hypothesis that there was no difference between transfused and non-transfused patients within (not between) each study group.

Comorbidity, %	NL Group			Other Group			NM Group		
	Transfusion (n=44)	No transfusion (n=407)	P	Transfusion (n=61)	No Transfusion (n=155)	P	Transfusion (n=161)	No transfusion (n=356)	P
Pulmonary comorbidity *	-	-	-	34.4	32.3	0.751	32.9	19.9	0.002
GI comorbidity *	-	-	-	36.1	30.3	0.422	42.2	31.7	0.022
Cardiac comorbidity *	-	-	-	29.5	30.3	1.000	14.3	10.1	0.180
Neurological comorbidity *	-	-	-	70.5	68.4	0.870	100.0	100.0	1.000
Cerebral Palsy	-	-	-	0.0	0.0	-	88.2	83.7	0.230
Developmental delay/ impaired cognitive status	-	-	-	52.5	51.6	1.000	85.7	71.3	<0.001
Seizure disorder	-	-	-	27.9	14.8	0.033	56.5	49.4	0.154
Structural CNS Abnormality	-	-	-	39.3	24.5	0.044	46.0	33.1	0.006
Immune disease	-	-	-	0.0	3.2	0.325	1.2	0.3	0.230
Steroid use	-	-	-	1.6	2.6	1.000	3.7	2.8	0.589
Nutritional support (IV or NG)	-	-	-	23.0	15.5	0.234	37.9	32.0	0.194
Bleeding disorder *	-	-	-	3.3	0.6	0.193	1.2	1.1	1.000
Hematologic disorder *	-	-	-	6.6	3.2	0.275	2.5	1.4	0.470
Pharmacologic inotrope use during operation	2.3	1.5	0.515	6.6	3.9	0.473	3.1	0.8	0.115
Preop blood transfusion	0	0.2	1.000	0.0	0.0	-	0.6	0.8	1.000
ASA Score 3	9.1	5.9	0.338	65.6	49.0	0.034	75.8	66.6	0.039
Prior operation within 30 days	0	1.0	1.000	1.6	2.6	1.000	1.2	0.6	0.592

NM = neuromuscular, NL = otherwise normal, Other = other non-NM disease comorbidity, ASA = American Society of Anesthesiologists, GI = gastrointestinal, IV = intravenous, NG = nasogastric.

* Detailed explanations of conditions included in grouped comorbidities (e.g., pulmonary comorbidity) are given in Supplement S1.

Table 3

Abnormal preoperative lab value association with transfusion. Statistical analysis was performed using Fisher's exact test. P values are with respect to the null hypothesis that there was no difference between transfused and non-transfused patients within (not between) each study group.

Parameter, %	NL Group			Other Group			NM Group		
	Transfusion (n=44)	No transfusion (n=407)	P	Transfusion (n=61)	No transfusion (n=155)	P	Transfusion (n=161)	No transfusion (n=356)	P
Hypoalbuminemia	0.0	0.0	-	0.0	0.6	1.000	1.2	0.3	0.230
Hyponatremia	0.0	1.0	1.000	3.3	1.3	0.317	2.5	0.0	0.009
Anemia*	0.0	1.2	1.000	3.3	3.9	1.000	3.1	0.3	0.013
Elevated WBC	0.0	1.5	1.000	1.6	0.6	0.486	0.0	1.4	0.331
Thrombocytopenia	9.1	2.2	0.029	3.3	3.9	1.000	7.5	1.7	0.003
Abnormal PTT	2.3	2.5	1.000	6.6	1.9	0.101	3.7	2.0	0.239
Abnormal PT	2.3	2.2	1.000	3.3	5.2	0.729	5.6	1.4	0.015

NM = neuromuscular, NL = otherwise normal, Other = other non-NM disease comorbidity, WBC = white blood cell, PTT = partial thromboplastin time, PT = prothrombin time.

* Anemia determined by preoperative hematocrit, not hemoglobin; NSQIP does not include hemoglobin labs.

Table 4

Independent risk factors for receiving a perioperative blood transfusion. Statistical analysis was performed using multivariate logistic regression. Variables from the univariate analysis were entered in the multivariate analysis if $p \leq 0.2$. Criteria were considered significant with $p \leq 0.05$. [†]Per hour increase. [‡] Per year increase.

Factor	P	OR	95% CI
NL Group			
Acetabular Osteotomy	0.004	3.655	1.522-8.779
Female Gender	0.008	3.546	1.399-9.009
Total Operative time [†]	<0.001	2.434	1.816-3.261
Patient age [‡]	<0.001	1.289	1.173-1.416
Other Group			
Acetabular osteotomy	0.020	7.737	1.383-43.294
Combined acetabular/femoral osteotomy	0.045	5.484	1.036-29.027
Total Operative time [†]	<0.001	1.563	1.238-1.974
NM Group			
Anemia (Preoperative Hct < 31%)	0.013	18.424	1.827-185.826
Developmental Delay/impaired cognitive status	0.004	2.366	1.323-4.229
Pulmonary comorbidity	0.032	1.729	1.049-2.849
Total operative time [†]	<0.001	1.641	1.418-1.900

NM = neuromuscular, NL = otherwise normal, Other = other non-NM disease comorbidity, ASA = American Society of Anesthesiologists, Hct = hematocrit, OR = odds ratio, CI = confidence interval.

Table 5

Patient outcome association with receiving a perioperative blood transfusion. Statistical analysis was performed using Fisher's exact test and independent sample t-test where appropriate. P values are with respect to the null hypothesis that there was no difference between transfused and non-transfused patients within (not between) each study group. Continuous variables are expressed as mean $\pm$ standard deviation.

Parameter	NL Group			Other Group			NM Group		
	Transfusion (n=44)	No transfusion (n=407)	P	Transfusion (n=61)	No transfusion (n=155)	P	Transfusion (n=161)	No transfusion (n=356)	P
Length of stay (days)	3.8 $\pm$ 1.5	2.4 $\pm$ 1.8	<0.001	6.1 $\pm$ 8.1	3.0 $\pm$ 3.0	<0.001	5.9 $\pm$ 5.3	4.2 $\pm$ 4.9	<0.001
Nerve injury, %	0.0	0.0	-	0.0	0.6	1.000	0.0	0.3	1.000
Renal insufficiency, %	0.0	0.0	-	0.0	0.0	-	0.6	0.0	0.311
Wound dehiscence, %	0.0	0.0	-	1.6	0.0	0.282	0.0	0.8	0.556
Unplanned reintubation, %	0.0	0.0	-	4.9	0.0	0.022	3.7	1.1	0.078
CVA, %	0.0	0.0	-	1.6	0.0	0.282	0.0	0.0	-
Infection, %									
Superficial SSI	0.0	0.5	1.000	1.6	0.6	0.486	1.2	0.3	0.230
Deep SSI	0.0	0.2	1.000	0.0	0.0	-	0.6	0.3	0.526
Organ/space SSI	0.0	0.0	-	0.0	0.0	-	0.0	0.3	1.000
Sepsis	0.0	0.2	1.000	0.0	0.0	-	1.9	0.8	0.381
Pneumonia	0.0	0.2	1.000	8.2	0.0	0.002	3.7	1.7	0.205
UTI	0.0	0.5	1.000	0.0	0.0	-	2.5	0.6	0.079
AAE, %	0.0	1.7	1.000	13.1	1.3	0.001	10.6	5.1	0.036
Readmission, %	0.0	3.2	0.626	4.9	5.8	1.000	5.6	5.3	0.504
Reoperation, %	0.0	2.7	0.611	0.0	1.9	0.560	1.9	2.2	1.000

NM = neuromuscular, NL = otherwise normal, Other = other non-NM disease comorbidity, CVA = cerebrovascular accident, SSI = surgical site infection, AAE = any adverse event.

Table 6

Patient outcomes associated with receiving a transfusion volume greater than 15 mL/kg. Statistical analysis was performed using Fisher's exact test and independent sample t-test where appropriate. P values are with respect to the null hypothesis that there was no difference between transfusions > 15 mL/kg and transfusions < 15 mL/kg within (not between) each study group. Continuous variables are expressed as mean ± standard deviation.

Parameter	NL Group			Other Group			NM Group		
	Transfusion > 15 mL/kg (n=7)	Transfusion < 15 mL/kg (n=37)	P	Transfusion > 15 mL/kg (n=24)	Transfusion < 15 mL/kg (n=37)	P	Transfusion > 15 mL/kg (n=67)	Transfusion < 15 mL/kg (n=94)	P
Length of stay (days)	3.3 ± 1.0	3.8 ± 1.6	0.372	6.0 ± 6.5	6.1 ± 9.0	0.960	6.3 ± 5.6	5.6 ± 5.2	0.396
Nerve injury, %	0.0	0.0	-	0.0	0.0	-	0.0	0.0	-
Renal insufficiency, %	0.0	0.0	-	0.0	0.0	-	0.0	1.1	1.000
Wound dehiscence, %	0.0	0.0	-	4.2	0.0	0.393	0.0	0.0	-
Unplanned reintubation, %	0.0	0.0	-	8.3	2.7	0.556	3.0	4.3	1.000
CVA, %	0.0	0.0	-	0.0	2.7	1.000	0.0	0.0	-
Infection, %									
Superficial SSI	0.0	0.0	-	4.2	0.0	0.393	3.0	0.0	0.172
Deep SSI	0.0	0.0	-	0.0	0.0	-	1.5	0.0	0.416
Organ/space SSI	0.0	0.0	-	0.0	0.0	-	0.0	0.0	-
Sepsis	0.0	0.0	-	0.0	0.0	-	0.0	3.2	0.267
Pneumonia	0.0	0.0	-	12.5	5.4	0.373	6.0	2.1	0.235
UTI	0.0	0.0	-	0.0	0.0	-	0.0	4.3	0.142
AAE, %	0.0	0.0	-	25.0	5.4	0.048	10.4	10.6	1.000
Readmission, %	0.0	0.0	-	4.2	5.4	1.000	7.5	8.5	1.000
Reoperation, %	0.0	0.0	-	0.0	0.0	-	3.0	1.1	0.571

NM = neuromuscular, CVA = cerebrovascular accident, SSI = surgical site infection, AAE = any adverse event.