〈 Clinical Research 〉

Preoperative Anemia in Hindfoot and Ankle Arthrodesis

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Abstract: *This is a retrospective study (n = 39) evaluating the postoperative outcomes of patients with mild to moderate preoperative anemia who underwent a hindfoot and/or ankle arthrodesis. In the study, 32 patients did not have preoperative anemia, and 7 had preoperative anemia. Mortality, length of hospital stay, blood transfusions, deep-vein thrombosis, infection, time to union, malunion, delayed union, nonunion, and ulceration were of particular interest. Comparative analyses between patients with preoperative anemia and those without were performed utilizing the independent samples t-test or by the nonparametric Mann-Whitney U-test. The Fisher exact test was used to analyze categorical data. The Shapiro-Wilk test was utilized to check normality. Statistical significance was defined at a 2-sided level of P <.05. Delayed union, nonunion, and malunion were all significantly increased in patients with preoperative anemia (P = .032, P = .004, and P = .028, respectively). Accordingly, the median total number of noninfectious complications (delayed union + nonunion + malunion) in patients with preoperative anemia (0.86 ± 0.38) was significantly higher than in patients without preoperative anemia (0.063 ± 0.25; P < .001). Patients with preoperative anemia had a significantly longer length of hospital stay in days (4.14 ± 2.61). Total infection was also significantly associated with preoperative anemia (P = .001). This study clearly demonstrated that infectious complications, noninfectious complications, and length of hospital stay in hindfoot and/or ankle arthrodesis was significantly affected by preoperative anemia. Thus, consideration should be given to addressing preoperative anemia prior to hindfoot and/or ankle arthrodesis.*

Levels of Evidence: *Level II Study*

Keywords: heel; rearfoot; ankle; surgical complications; general disorders; comorbid conditions

Introduction

Preoperative anemia has been identified as an independent risk factor for postoperative complications, including mortality, increased length of hospital stay, infection, and transfusions.[1-5] Anemia, defined as a reduced circulating red blood cell count, is best characterized on a continuous severity score and is categorized as normal, mild, moderate, or severe. Anemia has many influencing factors, including age, gender, race, tobacco use, and geographic location above or below sea level. For this reason, there is no single best definition of anemia because a patient may be functionally anemic based on their various physiognomies. However, recognizing asymptomatic reductions in circulating red blood cells represents an opportunity to reduce presurgical risk, which is often overlooked.

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Preoperative anemia is exceedingly common among patients undergoing

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elective surgery, who represent nearly 33% of this population.[6] Anemia, most commonly established in the elderly, is often considered a disease of frailty. It has been positively correlated with numerous chronic disease states such as cardiac disease, diabetes, renal dysfunction, and so on.[6] A study conducted in 2003 in US nursing homes found that of this population, nearly 40% of residents had some degree of anemia.[7,8]

Recent literature in noncardiac-related surgery has suggested that preoperative anemia is associated with increased postoperative mortality, blood transfusions, infection, and length of hospital stay. Moreover, preoperative anemia has also been evaluated in several orthopedic investigations involving hip and/or knee surgery. These data suggest that preoperative anemia is associated with increased postoperative infections, length of hospital stay, blood transfusion rates, and mortality.[1-5,9-11] In a retrospective study of more than 15 000 patients who underwent total joint arthroplasty of the hip or knee, postoperative joint infection was significantly higher (4.3%) in anemic patients compared with (2.1%) nonanemic patients ($P < .01$). Furthermore, the length of hospital stay after orthopedic surgery was significantly longer for anemic patients (4.3-10.0 days) compared with nonanemic patients (3.9-8.2 days).[5] Understandably, transfusion rates for anemic patients are also significantly higher at 42% to 71% compared with 10.5% to 12% in nonanemic patients.[5,8,12] Many of these studies have been performed on large joint reconstructions, which may not be an equivocal comparison to foot and ankle arthrodesis because this often represents a hypovolemic anemic patient population.

Hindfoot and ankle arthrodesis relieves pain, provides stability, and reduces deformity in patients with end-stage arthritis.[13,14] Long-term results demonstrate that more than 90% of patients are satisfied after arthrodesis; nevertheless, postoperative complications do arise.[15] Traditionally, risk factors that can affect bone and soft-tissue healing have been minimized, which include diabetes mellitus, inflammatory arthropathies, tobacco smoking, and steroid dependence. However, numerous orthopedic evaluations in the knee and hip suggest that patients with preoperative anemia have an increased length of hospital stay, higher rate of postoperative infections, and increased mortality.[16-18]

Following a review of the literature our team believes that normovolemic, anemic patients who undergo hindfoot and ankle procedures are at an increased risk of developing immediate postoperative complications, such as deep venous thrombosis, increased length of stay, and need for blood transfusion. Additionally, we believe that normovolemic, anemic patients who undergo hindfoot and ankle procedures are placed at an increased risk of developing infectious and osseous postoperative complications, such as deep infection, superficial infection, dehiscence, delayed union, nonunion, and malunion. This information might be of value because no preoperative anemia data exist for the foot and ankle population.

Patients, Materials, and Methods

On May 10, 2013, the institutional review board approved this study. A retrospective review of patient charts, radiographs, and operative reports with diagnosis codes for arthrodesis of the ankle, subtalar, talonavicular, calcaneocuboid, and tibiotalocalcaneal joints were assembled. The patients underwent surgery from 2007 to 2013. Patients were excluded if medical documentation was incomplete or if they were <18 years old. Preoperative anemia, mortality, length of hospital stay, blood transfusions, deep-vein thrombosis, superficial infection, deep infection, time to union, malunion, delayed union, nonunion, ulceration, age, sex, and body mass index (BMI) were retrospectively compared in patients who underwent a hindfoot and/or ankle arthrodesis. The World Health Organization defines preoperative anemia as a hemoglobin concentration ≤12 g/dL for women and ≤13 g/dL for men[6] (Table 1). At our institution, the internal medicine department managed all postoperative hemoglobin levels and was ultimately responsible for transfusion decisions. Generally, a blood transfusion was performed when the patient's hemoglobin was <8 g/dL or in symptomatic patients with hemoglobin between 8 and 10 g/dL, per hospital protocol.

The type of fixation and use of orthobiologics were determined by the attending surgeon. All patients who underwent hindfoot or ankle arthrodesis in this study received internal fixation, orthobiologics, or bone graft supplementation. Additionally, every participant also received preoperative antibiotics and a sequential compression device, both intraoperatively and during the hospital admission. A thigh tourniquet was used for the surgery unless it was contraindicated. Patients were discharged from the hospital in a cast and typically reevaluated at 2 weeks for suture removal and recasting. Subsequent monthly visits were standard unless a complication developed. Oblique, anteroposterior, and lateral radiographs were obtained to assess healing. Patients were transitioned to a fracture walker and then to a sneaker following adequate bone healing, as determined by radiographic evidence of greater than 50% osseous bridging.

Comparative analysis of continuous demographic and clinical variables between patients with and without preoperative anemia undergoing hindfoot and ankle arthrodesis was performed utilizing the independent-samples *t*-test or the nonparametric Mann-Whitney *U*-test, when the assumption of normality was violated. The Fisher exact test was used to analyze categorical data. The Shapiro-Wilk test was used to check normality. Statistical significance was defined at a 2-sided *P* value <.05. Statistical analyses were performed using IBM SPSS Statistics software, version 20.0 (IBM Corporation, Armonk, NY).

Table 1.

Hemoglobin Levels (g/dL) to Diagnose Anemia at Sea Level.

Population	Nonanemia	Mild	Moderate	Severe
Children 12-14 years	12.0 or higher	11.9-11.0	10.9-8.0	<8.0
Nonpregnant women > 15 years	12.0 or higher	11.9-11.1	10.9-8.0	<8.0
Men > 15 years	12.0 or higher	12.9-11.0	10.9-8.0	<8.0

Results

A total of 39 individuals, 56.4% of whom were female met the inclusion criteria. There were 32 nonanemic patients who underwent 6 different rearfoot arthrodesis procedures: tibiotalonavicular arthrodesis, ankle arthrodesis, triple arthrodesis, medial double arthrodesis, subtalar arthrodesis, and talonavicular arthrodesis. The 7 anemic patients underwent 4 different rearfoot arthrodesis procedures: tibiotalonavicular arthrodesis, ankle arthrodesis, triple arthrodesis, and medial double arthrodesis. In our historical data, no patient with determined presurgical anemia underwent isolated subtalar joint arthrodesis or isolated talonavicular joint arthrodesis. In patients who met inclusion criteria, 17.9% were determined to have had preoperative anemia. In the anemic group, 53% were classified as mildly anemic (11.0-11.0 g/dL), 43% were determined to be moderately anemic (8.0-10.0 g/dL), and none was identified as severely anemic (lower than 8.0 g/dL). The mean patient age was 57 ± 15 years (Table 2).

To better define our patient population, data on comorbidities were collected and compared to assess for significance. Several variables were most commonly seen within the patient population (arthritis, hypertension, diabetes, heart disease, gastroesophageal reflux disease, anxiety/depression, and vitamin D deficiency). In this study, no significant association was seen between preoperative anemia and the above-mentioned comorbidities, with the exception of heart disease, which reached statistical significance ($P = .023$). Comparison of the mean age, gender, height, and weight between patients with preoperative anemia and those without revealed no significant differences ($P = .37$). Additionally, patient gender, height, weight, and BMI were not significantly associated with incidence of preoperative anemia (Table 3).

Table 2.

Patient Demographics and Surgical Procedures in Both Anemic and Nonanemic Patient Groups.

Characteristic	Nonanemic Group (n = 32)	Anemic Group (n = 7)
Sex (%)		
Female	16 (50)	6 (83)
Male	16 (50)	1 (17)
Age (years)		
Mean (SD)	59.6 (15.6)	61.6 (9.8)
Body mass index (kg/m^2)		
Mean (SD)	32.5 (7.1)	31.5 (7.9)
Surgery type (%)		
Tibiotalonavicular	3 (25)	2 (29)
Ankle arthrodesis	7 (22)	1 (14)
Triple arthrodesis	8 (25)	3 (43)
Medial double arthrodesis	8 (25)	1 (14)
Isolated STJ arthrodesis	4 (12.5)	0 (0)
Isolated TN arthrodesis	2 (6)	0 (0)

Abbreviations: STJ, Subtalar Joint; TN, Talonavicular.

For simplicity of presentation, complications were divided into 3 primary categories (immediate postoperative, infectious, and osseous complications). Immediate postoperative complications are defined as follows: blood transfusions, length of stay, and deep venous thrombosis. Patients with preoperative anemia had a significantly

longer median length of hospital stay (4.14 ± 2.61) than patients without preoperative anemia (2.22 ± 1.29; P = .014). Length of stay was not significantly associated with the total number of comorbidities because the range of comorbidities ranged from 0 to 5. No patient in the study had deep-vein thrombosis. No patient in the study died, and thus, there was no mortality. When summarized, the presence of postoperative complications (noninfectious complications + total infection + ulceration) was significantly associated with preoperative anemia (P < .001). Of the 12 patients with a complication, 58.3% had preoperative anemia. The median duration of follow-up in days among patients with preoperative anemia (542.57 ± 492.66) did not significantly differ from that of patients without preoperative anemia (385.16 ± 423.86; P = .12). In this study, preoperative anemia was not significantly associated with receiving a blood transfusion (P = .18). Only 1 patient required a blood transfusion, which was determined necessary per hospital protocol (Table 4).

Osseous complications are defined as follows: time to weight bearing, delayed union, nonunion, malunion, and time to union. The median non–weight-bearing weeks among patients with preoperative anemia (11.14 ± 2.97) was not significantly different from that of patients without preoperative anemia (9.38 ± 2.83; P = .15). The median clinical time to union, measured in weeks (12.40 ± 6.80), was not statistically significant (P = .61). For this variable, data existed on 5 of the 7 patients with preoperative anemia because 2 of the patients had a nonunion and never achieved clinical union. The median time to radiographic union in weeks among patients with preoperative anemia (22.60 ± 4.51) was significantly longer than in patients without preoperative anemia (17.44 ± 5.22; P = .024). For this variable also, data existed on 5 of the 7 patients with preoperative anemia because 2 of the patients had a nonunion and never achieved radiographic union. No significant association was made between patients' comorbidities and the presence of osseous complications following surgery. Delayed unions were significantly associated with whether or not a patient had preoperative anemia (P = .032). Of the 5 patients with delayed union, 60% had preoperative anemia. Nonunion was also significantly associated with the presence of preoperative anemia (P = .004). Of the 3 patients with nonunion, 100% had preoperative anemia. Additionally, malunion was significantly associated with whether or not a patient had preoperative anemia (P = .028). Of the 2 patients with malunion, 100% had preoperative anemia. The median total number of noninfectious complications (delayed union + nonunion + malunion) in patients with preoperative anemia (0.86 ± 0.38) was significantly higher than in patients without preoperative anemia (0.063 ± 0.25; P < .001; Table 5).

Table 3.

Comparison Between Anemic and Nonanemic Patients' Comorbidities.[a]

Characteristics	Nonanemic Group, n = 26	Anemic Group, n = 7	*P* Value
GERD (%)	5 (19)	1 (2)	.91
Cardiac conditions (%)	3 (15)	4 (15)	.023
Hypertension (%)	5 (19)	2 (7)	.41
Vitamin D deficiency (%)	4 (15)	0 (0)	.44
Depression/Anxiety (%)	2 (7)	1 (14)	.2
Diabetes (%)	12 (46)	1 (14)	.2
Arthritis (%)	5 (19)	2 (28)	.42
Tobacco use (%)	2 (7)	1 (14)	

Abbreviation: GERD, gastroesophageal reflux disease.
[a]The independent-samples t-test was used to determine significance. Statistical significance was defined at a 2-sided P value <.05.

Table 4.

Immediate Postoperative Outcome Comparison Between Anemic and Nonanemic Patients.[a]

Characteristics	Nonanemic (n = 32)	Anemia Group (n = 7)	*P* Value
Length of stay			
Mean (SD)	2.22 (1.29)	4.14 (2.61)	.014
Deep-venous thrombosis (%)	0 (0)	0 (0)	
Transfusions (%)	0 (0)	1 (14.3)	.18

[a]The independent-samples t-test was used to determine significance. Statistical significance was defined at a 2-sided P value of <.05.

Infectious complications in this study are defined as follows: superficial infection, deep-space infection, and total infection. A total of 7 infections occurred in this study population. The presence of superficial infection was significantly associated with whether or not a patient had preoperative anemia ($P = .006$; Table 6). Of the 6 patients with superficial infection, 66.7% had preoperative anemia. Conversely, the presence of deep infection was not significantly associated with whether or not a patient had preoperative anemia ($P = .18$; Table 6). However, total infection (superficial infection + deep infection) was significantly associated with preoperative anemia ($P = .001$; Table 6). Of the 7 patients with infections, 71.4% had preoperative anemia. The presence of ulceration was not significantly associated with preoperative anemia ($P = .059$). There was no statistically significant association with the presence of anemia and postoperative complication of infection (Table 6).

Table 5.

Osseous Postoperative Outcome Comparisons Between Anemic and Nonanemic Patients.[a]

Characteristics	Nonanemic Group (n = 32)	Anemic Group (n = 7)	*P* Value
Time to union (days)			
Mean (SD)	17.44 (5.22)	24.0 (4.51)	.024
Delayed union (%)	2 (40)	3 (60)	.032
Nonunion (%)	0 (0)	3 (100)	.004
Malunion (%)	0 (0)	2 (100)	.028
Time to weight bearing			
Mean (SD)	8.09 (5.52)	18.0 (19.97)	.09
All osseous complications			
Mean (SD)	0.063 (0.25)	0.86 (0.38)	<.001

[a]Confidence interval set at $P = .05$. The independent-samples t-test was used to find significance. Statistical significance was defined at a 2-sided P value of <.05.

Table 6.

Infectious Postoperative Outcome Comparisons Between Anemic and Nonanemic Patients.[a]

Characteristics	Nonanemic Group (n = 32)	Anemic Group (n = 7)	*P* Value
Superficial infection (%)	2 (33)	4 (67)	.006
Deep-space infection (%)	0 (0)	1 (14)	.18
Total infection (%)	2 (33)	5 (7)	.001

[a]The independent-samples t-test was used to find significance. Statistical significance was defined at a 2-sided level of $P < .05$.

Discussion

The aim of this study was to establish a suspected cause-and-effect relationship between mild to moderate normovolemic anemia and the risk of developing postsurgical complications. The data revealed increased complications and lengths of stay in anemic patients compared with nonanemic patients. Given the paucity of foot and ankle–related preoperative anemia literature, we can only cite large joint literature, which show that the incidence of preoperative anemia is 15% to 20%. After reviewing our data, we find this to be consistent with our study value of 18%.[5,8,19] Likewise, numerous other agreements exist between our data and those in the vast joint orthopedic literature. Similar to Greenky et al,[5] our results suggest an increased infection rate. Weinberg first established the affect of anemia on infection rate in the early 1970s, coining the term *nutritional immunity*.[20] It was originally believed that limiting hemoglobin and, thus, iron stores reduced the food supplies of bacteria and, thus, created a functional immunity. This concept was disputed with the discovery of bacterial siderophores, which established the capability of bacteria to extract iron without excessive efforts.[21] From our study, we believe that individuals with preoperative anemia do not appear to display any functional immunity from infection and may be at increased risk. Though not completely established in the literature, this may be a result of reduced oxygen saturation at the surgical incision site.

Anemia has been used as a marker for presurgical health in several non–cardiac-related studies. Much like exercise, postoperative "healing" increases an individual's metabolic demands, which requires significant oxygen-carrying capacity. The preoperative partial pressure of oxygen in venous blood has been used as a measure of preoperative

fitness. When low, it has been suggested to be a strong indicator of negative outcomes postoperatively.[19,22] Similar to preoperative anemia, no current association has been made between degree of oxygen saturation and risk of postoperative complications, and thus, this testing modality has little clinical relevance currently.

The anemic patient is 3 times more likely to undergo blood transfusion following their operation, which is not without its risks.[23] In a study performed by Ferraris et al,[12] patients who were transfused with 1 unit of packed red blood cells demonstrated multivariant increased risk of mortality, pulmonary complications, renal dysfunction, sepsis, wound problems, and increased length of stay as compared with individuals who did not receive transfusions.[9] Other similar investigations have found increased risk of mortality in patients with mild anemia and concomitant heart disease or excessive intraoperative blood loss.[4] In our study population, we found no increased risk of blood transfusion. We attribute this to the limited blood loss associated with foot and ankle surgery. This highlights our theory that the current literature analyzing preoperative anemia within orthopedic surgery describes primary hypovolemic anemia, which may pose different risk factors.

Furthermore, the length of hospital stay in our study was significantly longer at 4.1 days, which is also similar to that in Greenky et al,[5] at 4.3 days in anemic patients. Moreover, overall infection in our study was significantly higher (71% vs 6%) in the anemic group, which is in agreement with the values in the hip and knee literature (4.3% vs 2%). After reviewing our charts, it is unclear why patients with preoperative anemia stayed significantly longer. Often, issues with pain control, active drains, and postoperative placement were indicated as reasons; however, it is difficult to establish clear cause and effect of length of stay in this patient population.

Within our study results, one of the most significant and alarming were the noninfectious complications (87% vs 6%), which has not been found in other orthopedic evaluations. From the data presented in this study, we believe that even mild to moderate preoperative anemia may have a large impact on a patient's ability to ossify osteotomies. Studies performed on anemic rodents suggested that normovolemic anemia might be correlated with reduction in rate of union and absences of callus strength. This team suggested that an aberration to the oxygen tension and reduction in iron reserves creates deficits in critical components for appropriate functioning of proline hydroxylation. It is their assertion that this deficiency leads to abnormal bone ossification, which places an individual at an increased risk of nonunion, malunion, and delayed union. These findings agree with our data. In our population, we found that patients showed evidence of callus formation and clinical union at an average rate consistent with that in our controls. Once the patient initiated weight bearing, it was found that there was a delay in achieving full union and an increased likelihood of developing a malunion. We attribute this to disruption in hydroxylation of proline and aberration in the ossification.

Our study clearly demonstrated that infection, noninfectious complications, and lengths of hospital stay in hindfoot and ankle arthrodesis were significantly affected by the presence of preoperative anemia. Thus, consideration should be given to address preoperative anemia prior to hindfoot and ankle arthrodesis. At this time, no suggestions related to severity of anemia and risk of complications have been made. As mentioned before, anemia exists on a severity spectrum that is based on a person's physiognomy. Unlike preoperative hemoglobin glycation, no identifiable number has been established to signify risk.

There are several limitations to this study, including the following: (1) The sample size was small, with an unequal proportion of patients within each cohort, which may result in unreliable findings and limits our ability to apply the data to larger populations; (2) the study was based on findings in a single health network academic medical center and, therefore, may not be applicable to a broader population. However, given the uniformity of these findings when compared with other orthopedic literature, we believe that these limitations have minimal bearing on the validity of this study.

A treatment protocol has been suggested by multiple studies, which addresses both mild and moderate anemia correction.[19,22,24] Correction of preoperative anemia is best performed as part of presurgical workup. The crux of therapy is based on the cause of anemia. With this said, collaborative care of presurgical patients is always advised.

The data found in this study suggest that a strong risk of postoperative complications exists in patients who are mildly to moderately anemic. Complications of surgery were not strongly associated with other comorbidities and may represent several nutritional deficiencies that arise when circulating hemoglobin levels are low. Although there appears to be a strong indication of increased risk, many questions still exist regarding preoperative anemia in foot and ankle surgery, and further investigation is required to correlate the severity of an individual's preoperative anemia with the inherent risk of developing postoperative complications.

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