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Factors associated with delays in medical and surgical open facial fracture management

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ABSTRACT

Objectives Open fractures are at risk of infection because of exposure of bone and tissue to the environment. Facial fractures are often accompanied by other severe injuries, and therefore fracture management may be delayed until after stabilization. Previous studies in this area have examined timing of multiple facets of care but have tended to report on each in isolation (eg, antibiotic initiation).

Methods This was a retrospective study of adult patients admitted to five trauma centers from January 1, 2017 to March 31, 2021 with open facial fractures. Variables collected included demographics, injury mechanism, details on facial and non-facial injuries, facial fracture management (irrigation and debridement (I&D), irrigation without debridement, open reduction internal fixation (ORIF), antibiotics), and other hospital events. The study hypothesized that the presence of serious non-facial injuries would be associated with delays in facial fracture management. The primary aims were to describe open facial fracture management practices and examine factors associated with early versus delayed fracture management. A secondary aim was to describe infection rates. Early treatment was defined as within 24 hours of arrival for I&D, irrigation without debridement, and ORIF and within 1 hour for antibiotics.

Results A total of 256 patients were included. Twenty-seven percent had major trauma (Injury Severity Score ≥16). The presence of serious head injury/traumatic brain injury was associated with delayed I&D (OR_{early}=0.04, p<0.01), irrigation without debridement (OR_{early}=0.09, p<0.01), and ORIF (OR_{early}=0.10, p<0.01). Going to the OR within 24 hours was associated with early I&D (OR_{early}=377.26, p<0.01), irrigation without debridement (OR_{early}=13.54, p<0.01), and ORIF (OR_{early}=154.92, p<0.01). The infection rate was 4%.

Conclusions In this examination of multiple aspects of open facial fracture management, serious injuries to non-facial regions led to delays in surgical fracture management, consistent with the study hypothesis.

Level of evidence Level III, prognostic/epidemiological.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Management of open facial fractures is often delayed because of other serious injuries requiring emergency triage. Previous studies have tended to examine only single aspects of facial fracture management and have reported conflicting findings on the impact of delayed management on infection.

WHAT THIS STUDY ADDS

⇒ This study was an investigation of factors associated with delays in multiple aspects of open facial fracture management—including prophylactic antibiotics, irrigation and debridement, irrigation without debridement, and open reduction internal fixation. A secondary study aim described infection rates according to fracture management practices. The results showed that the presence of severe non-facial fractures led to delays in facial fracture management, consistent with the study hypothesis.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study found that the presence of concomitant severe non-facial injuries led to delayed facial fracture management, thereby identifying a patient population that could be targeted for efforts to improve open facial fracture management timing.

BACKGROUND

Open fractures are at increased risk of infection because of exposure of tissue and bone to the environment, and common treatment protocols involve early initiation of prophylactic antibiotics, wound irrigation and debridement (I&D), and surgical stabilization and repair of the fracture, for example, via open reduction internal fixation (ORIF).[1–4] Despite infection rates as high as 20% to 40%,[5 6] open fractures of the face are more likely to receive delayed treatment than open fractures of other locations. Facial fractures are often accompanied by other, more severe injuries such as head trauma requiring immediate surgical intervention, pulmonary injuries or an obstructed airway requiring intubation or tracheostomy, rib fractures, or cervical spine injury; this is especially true with high-energy mechanisms of injury such as motor vehicle collisions.[7–14] These concurrent injuries can be life-threatening and may require delaying management of the open facial fracture until the patient has stabilized.

Previous studies have generally examined the effects of single aspects of open facial fracture management on infection. For example, it has been

demonstrated that short courses of prophylactic antibiotics are generally effective at reducing infection rates during the hospital stay but that postoperative or extended antibiotic courses do not further reduce infection risk.[5 6 15–22] Additionally, I&D, which is essential to remove debris and contaminants from the open fracture wound, has been shown to decrease infection.[23–29] The effects of early compared with delayed I&D have been reported in open extremity fractures, with studies showing that infection rates did not significantly differ when I&D was performed within 6 hours after hospital arrival, as recommended for open extremity fractures, versus later.[30–32] However, I&D timing has not been examined in the context of open facial fractures, which are at higher risk of delayed management compared with open extremity fractures.

Previous studies have tended to focus on single aspects of open facial fracture management, such as time to antibiotic initiation or surgical management in isolation. The hypothesis of the current study was that the presence of severe non-facial injuries would be associated with delays in multiple aspects of facial fracture management, including both medical and surgical practices. To address this hypothesis, this study aimed to describe multiple facets of open facial fracture management practices, including prophylactic antibiotics, I&D, irrigation without debridement, and ORIF, and examine factors associated with delays in each type of fracture management. A secondary study aim was to describe the rates of open facial fracture infection in this patient population, both overall and according to early versus delayed fracture management.

METHODS

This was a retrospective study of adult (age≥18 years) trauma patients admitted to five trauma centers (four ACS-verified level I, one state-designated level III) with open facial fractures between January 1, 2017 and March 31, 2021. Patients with isolated or non-isolated facial fractures as well as those with any Gustilo-Anderson open fracture type (I, II, IIIa, IIIb, IIIc) were included. Data were collected from the individual trauma registries at all participating facilities and patient electronic medical records. The study was approved by the Institutional Review Boards of all participating trauma centers (CommonSpirit Health Research Institute IRB, Englewood, CO, study 1758565–2; Medical City Plano Institutional Review Board, Plano, TX, study 1758564–6; and HCA-HealthONE IRB, Denver, CO, study 1758563–3) and was granted a waiver of HIPAA and consent.

Variables collected on all patients included demographics (age, sex), injury mechanism (assault/stab/gunshot, motor vehicle/bicycle collision, fall, other), presence and severity (Abbreviated Injury Score, AIS) of non-facial injuries, Injury Severity Score (ISS), Glasgow Coma Scale (GCS) score, hospital length of stay (HLOS), intensive care unit (ICU) admission and LOS, emergency department (ED) discharge destination, total number of open facial fractures, open facial fracture location (mandible, nasal, maxillary, orbital, zygomas, frontal bone), Gustilo-Anderson type of all open facial fractures, trips to the operating room (OR), intubation, and tracheostomy. The following information about facial fracture management was collected: I&D, irrigations without debridement, ORIF, and prophylactic antibiotics. Fracture management was classified as early versus late in the following manner: for I&D, irrigation without debridement, and ORIF, treatment within 24 hours of hospital arrival versus later; previous studies have found no significant associations between delayed surgical management and infection in open facial fractures when a delay was defined as >48 hours[33 34] or >72 hours[35], and therefore 24 hours was chosen as a more stringent threshold for evaluation here. Early initiation of prophylactic antibiotics was defined as within 1 hour of hospital arrival, in accordance with EAST and TQIP guidelines for open fractures.[1 36] Infection was defined as a patient having an infection listed in the complication variable in the trauma registry—to qualify for documentation in the trauma registry as an infection, the patient must have at least one of the following: (1) purulent drainage from

Table 1 Demographics and clinical details of patients with open facial fractures

	Total, n=256
Demographics	
Age (median (IQR))	36 (26–51)
Sex (% female)	53 (21%)
Clinical characteristics	
ISS (median (IQR))	9 (5–17)
Emergency department GCS (median (IQR))	15 (14–15)
Other serious injuries (AIS≥3)	
Head	67 (26%)
Neck	23 (9%)
Thorax	16 (6%)
Abdomen	7 (3%)
Spine	6 (2%)
Upper extremity	1 (1%)
Lower extremity	1 (1%)
Facial fracture details	
Total open facial fractures	
1	180 (71%)
2	54 (21%)
3	9 (4%)
4	1 (1%)
5	2 (1%)
6	4 (2%)
7	3 (1%)
10	1 (1%)
Total open facial fractures	
1	180 (71%)
2	54 (21%)
3+	20 (8%)
Fracture location	
Mandible	135 (53%)
Nasal bone	84 (33%)
Maxillary bone	47 (19%)
Orbital bone	30 (12%)
Zygomas	21 (8%)
Frontal bone	7 (3%)
Highest type open facial fracture	
Type 1	63 (25%)
Type 2	60 (23%)
Type 3a	92 (36%)
Type 3b	29 (11%)
Type 3c	10 (4%)
OR and tracheostomy	
OR≤24 hour of arrival	145 (57%)
Tracheostomy	24 (9%)
Tracheostomy≤24 hour of arrival	12 (5%)

AIS, Abbreviated Injury Scale; GCS, Glasgow Coma Scale; ISS, Injury Severity Score; OR, operating room.

Table 2 Unadjusted and independent associations with treatment timing

	Early I&D		Early irrigation without debridement		Early ORIF		Early antibiotics	
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted
Moderate/severe TBI in the ED (GCS<13)	1.00 (0.33 to 3.01)		0.31 (0.12 to 0.77)	**0.09 (0.03 to 0.33)**	0.26 (0.10 to 0.65)	**0.10 (0.03 to 0.39)**	0.68 (0.36 to 1.28)	
Fracture location								
Nasal bone	0.85 (0.27 to 2.69)		13.36 (3.09 to 57.82)	**37.70 (7.32 to 194.17)**	0.94 (0.38 to 2.32)		1.17 (0.68 to 2.01)	
Maxillary bone	0.47 (0.17 to 1.36)	**0.05 (0.01 to 0.49)**	0.35 (0.12 to 0.98)		0.34 (0.15 to 0.79)	**0.14 (0.04 to 0.50)**	1.19 (0.62 to 2.29)	
Other serious injuries (AIS≥3)								
Head	0.40 (0.13 to 1.25)	**0.04 (0.01 to 0.39)**	0.85 (0.37 to 1.94)		0.33 (0.15 to 0.73)	**0.14 (0.04 to 0.48)**	0.98 (0.55 to 1.72)	
Neck	0.13 (0.02 to 1.15)		0.46 (0.13 to 1.65)		0.03 (0.01 to 0.61)		0.36 (0.15 to 0.88)	**0.39 (0.16 to 0.96)**
Abdomen	6.14 (0.14 to 262.26)		1.11 (0.12 to 10.22)		0.95 (0.13 to 6.90)	**35.90 (2.24 to 575.25)**	1.88 (0.36 to 9.90)	
OR≤24 hours of arrival	21.00 (2.53 to 173.93)	**377.26 (18.07 to 999.99)**	4.00 (1.79 to 8.93)	**13.54 (4.62 to 39.73)**	22.31 (8.02 to 62.08)	**154.92 (35.80 to 670.38)**	1.06 (0.64 to 1.76)	

Bold text indicates statistical significance at a threshold of p<0.05.
AIS, Abbreviated Injury Scale; ED, emergency department; GCS, Glasgow Coma Scale; I&D, irrigation and debridement; OR, operating room; TBI, traumatic brain injury.

the incision; (2) dehiscence of the incision wound (spontaneous or surgeon-inflicted) with organisms present identified either by culture or microbiologic testing and at least one of the following signs of symptoms: (a) fever (>38°C) or (b) localized pain or tenderness; or (3) an abscess or other evidence of infection of the incision detected on gross anatomic or histopathologic examination or imaging test—and a diagnosis of infection documented in the chart by the patient's physician, which was confirmed by manual chart review by clinical research coordinators that was conducted on all patients with an infection complication in the trauma registry.

The study hypothesis was that concurrent, serious non-facial injuries would be associated with delays in open facial fracture management. The two primary study aims to address this hypothesis were to (1) describe open facial fracture management practices and (2) examine factors associated with early versus delayed fracture management. The secondary study aim was descriptive in nature, reporting the rates of infection in the overall open facial fracture population and according to facial fracture management practices and facial fracture details. All patient variables listed above were examined for associations with early vs delayed treatment. χ^2, Fisher's exact, and Mann-Whitney U tests as well as unadjusted and adjusted logistic regression analyses were used to evaluate associations with early versus delayed open facial fracture management. The rate of infection was too low in this study population to allow for more than descriptive reporting of infection rates overall and according to varying facial fracture management practices; tables describing the rates of infection according to treatment practices and open facial fracture characteristics are shown as n (%) or median (IQR). SAS V.9.4 was used for all statistical analyses, and a significance threshold of $p \leq 0.05$ was used.

RESULTS

Patient population

The study included a total of 256 patients with open facial fractures (table 1). The median patient age was 36 years, and most (79%) were male. Twenty-seven percent (n=68) had major trauma/polytrauma (ISS≥16), 20% (n=49) had moderate or severe traumatic brain injury (TBI) (GCS<13), and 35% (n=90) had a serious (AIS≥3) injury to a non-facial body region, the most common of which was the head (26%, n=67). The most common injury mechanism was assault/stabbing/gunshot wound (39%, n=99), followed by motor vehicle/bicycle collision (28%, n=72). After leaving the ED, 36% (n=91) of patients were admitted to the floor, 32% (n=82) went to the ICU, and 19% (n=47) went to the OR or interventional radiology. The median HLOS was 3 days, 44% (n=112) of patients were admitted to the ICU during their hospital stay, and the median ICU LOS was 5 days.

Most patients (71%, n=180) had only one open facial fracture, and the most common location was the mandible (53%, n=135), followed by the nasal bone (33%, n=84). Twenty-five percent (n=63) of patients had a type I fracture as their highest-type open facial fracture, 23% (n=60) had a type II, 36% (n=92) had a type IIIa, 11% (n=29) had a type IIIb, and 4% (n=10) had a type IIIc fracture as their highest-type facial fracture.

Treatment details

Twenty-three percent of patients (n=60) underwent I&D, 67% (n=171) underwent irrigation without debridement, and the remainder (10%, n=25) did not receive any debridement or irrigation. Fifty-eight percent (n=148) of patients underwent ORIF,

Table 3 Descriptive statistics showing infection rates by fracture management practices and open facial fracture details

	All, n=256	Infection, n=9 (4%)	No infection, n=242 (96%)
Fracture management			
Irrigation and debridement			
I&D	60 (23%)	6 (67%)	53 (22%)
Irrigation with no debridement	171 (67%)	3 (33%)	166 (69%)
No irrigation or debridement	25 (10%)	0 (0%)	23 (10%)
ORIF	148 (58%)	9 (100%)	137 (57%)
Antibiotics	249 (98%)	9 (100%)	237 (98%)
Treatment timing, counts, and other details			
I&D			
Time to first I&D	27 (12–51)	32 (9–208)	26 (13–47)
I&D timing			
Early	28 (47%)	3 (50%)	25 (47%)
Delayed	32 (53%)	3 (50%)	28 (53%)
I&D count			
1	49 (82%)	2 (33%)	46 (87%)
2+	11 (18%)	4 (67%)	7 (13%)
Irrigation without debridement			
Time to first irrigation	6 (1–19)	40 (0–155)	6 (1–18)
Irrigation timing			
Early	134 (78%)	1 (33%)	131 (79%)
Delayed	37 (22%)	2 (67%)	35 (21%)
Irrigation count			
1	151 (88%)	3 (100%)	146 (88%)
2+	20 (12%)	0 (0%)	20 (12%)
Open reduction internal fixation			
Time to first ORIF	24 (11–50)	16 (9–53)	24 (11–49)
ORIF timing			
Early	76 (51%)	5 (56%)	71 (52%)
Delayed	72 (49%)	4 (44%)	66 (48%)
ORIF count			
1	113 (76%)	4 (44%)	107 (78%)
2+	35 (24%)	5 (56%)	30 (22%)
Antibiotics			
Time to antibiotic initiation	1 (0–3)	0 (0–2)	1 (0–3)
Initiation timing			
Early	143 (57%)	6 (67%)	136 (57%)
Delayed	106 (43%)	3 (33%)	101 (43%)
First antibiotic administered (class)			
Cephalosporin	123 (49%)	4 (44%)	117 (50%)
Combination, penicillin-beta lactam	72 (29%)	3 (33%)	69 (29%)
Lincomycin	46 (18%)	2 (22%)	42 (18%)
Penicillin	4 (2%)	0 (0%)	4 (2%)
Aminoglycoside	2 (1%)	0 (0%)	2 (1%)
Combination, penicillin-glycoprotein	1 (1%)	0 (0%)	1 (1%)
Nitroimidazole	1 (1%)	0 (0%)	1 (1%)
Initial antibiotic course (days, median (IQR))	1 (0–2)	1 (0–5)	1 (0–2)
Facial fracture details			
Total open facial fractures			
1	180 (71%)	5 (56%)	173 (71%)
2	54 (21%)	3 (33%)	50 (21%)
3+	20 (8%)	1 (11%)	19 (8%)
Fracture location			
Mandible	135 (53%)	8 (89%)	125 (52%)
Nasal bone	84 (33%)	1 (11%)	82 (34%)
Maxillary bone	47 (19%)	4 (44%)	43 (18%)
Orbital bone	30 (12%)	1 (11%)	29 (12%)
Zygomas	21 (8%)	0 (0%)	21 (9%)
Frontal bone	7 (3%)	1 (11%)	6 (2%)
Highest type open facial fracture			
Type 1	63 (25%)	4 (44%)	58 (24%)
Type 2	60 (23%)	0 (0%)	58 (24%)
Type 3a	92 (36%)	1 (11%)	91 (38%)
Type 3b	29 (11%)	1 (11%)	28 (12%)
Type 3c	10 (4%)	3 (33%)	7 (3%)

I&D, irrigation and debridement; ORIF, open reduction internal fixation.

and almost all patients (98%, n=249) received intravenous antibiotics. Among patients undergoing I&D, the median time to I&D was 27 hours, 47% (n=28) received early treatment, and 18% underwent at least two I&D procedures. Among those receiving irrigation with no debridement, the median time to irrigation was 6 hours, 78% (n=134) received early treatment, and 12% (n=20) received at least two irrigations. Among patients undergoing ORIF, the median time to ORIF was 24 hours, 51% (n=76) received early treatment, and 24% (n=35) underwent at least two ORIF procedures. Among patients receiving antibiotics, the median time to initiation was 1 hour, and 57% (n=143) received early treatment. For the initial prophylactic antibiotic course, 49% (n=123) received a cephalosporin-class antibiotic, 29% (n=72) received a penicillin-beta lactam combination, 18% (n=46) received a lincomycin, and 2% (n=4) received a penicillin alone. Other antibiotic classes administered as prophylactic courses included aminoglycoside (1%, n=2), a penicillin-glycoprotein combination (1%, n=1), and nitroimidazole (1%, n=1). The median prophylactic antibiotic course was 1 day.

Associations with early versus delayed treatment

In adjusted analyses, a number of patient factors were independently associated with early vs delayed open facial fracture management (table 2). Of note, table 2 only displays variables showing statistically significant associations; a table displaying all associations with early versus delayed treatment is included as online supplemental table 1. Among those receiving I&D, early treatment was associated with going to the OR within 24 hours of arrival (OR_{early}=377.26, p<0.01), and delayed treatment was associated with maxillary fractures (OR_{early}=0.05, p<0.01) and concomitant serious head injury (OR_{early}=0.04, p<0.01). Among patients receiving irrigation without debridement, early treatment was associated with nasal fractures (OR_{early}=37.70, p<0.01) and OR within 24 hours (OR_{early}=13.54, p<0.01), and delayed treatment was associated with moderate/severe TBI (OR_{early}=0.09, p<0.01). In patients undergoing ORIF, early treatment was associated with concomitant serious abdominal injury (OR_{early}=35.90, p=0.01) and OR within 24 hours (OR_{early}=154.92, p<0.01), and delayed treatment was associated with moderate/severe TBI (OR_{early}=0.10, p<0.01), maxillary fractures (OR_{early}=0.14, p<0.01), and concomitant serious head injury (OR_{early}=0.14, p<0.01). In patients that received antibiotics, delays in initiation were associated with concomitant serious neck injury (OR_{early}=0.39, p=0.04).

Description of infection rates

The overall fracture site infection rate was 4% (n=9) (table 3). Compared with patients without infection, a higher percentage

of patients with infection underwent I&D (67% vs 22% for no infection) than irrigation without debridement (33% vs 69% for no infection). Compared with patients without infection, a higher percentage of patients with infection who underwent I&D received at least two I&Ds (67% vs 13% for no infection) compared with only one I&D (33% vs 87% for no infection). Similarly, in patients with infection compared with those without infection undergoing ORIF, a higher percentage of those with infection underwent at least two ORIFs (56% vs 22% for no infection) compared with only one ORIF (44% vs 78% for no infection). Compared with patients without infection, a higher percentage of patients with infection had type IIIc open facial fractures (33% vs 3% for no infection).

DISCUSSION

This study investigated factors associated with delays in multiple facets of open facial fracture management, finding that approximately half of patients received early surgical fracture management. Although analyses of associations with infection were not possible because of the rarity of the outcome in this patient population, the percentage of patients developing infection did not appear to be substantially higher among those with delayed fracture management. Although previous studies have reported separately on the impact of individual aspects of open fracture management, such as I&D[23–29] and early initiation of antibiotics,[5 6 15–22] this study included prophylactic antibiotics, I&D, irrigation without debridement, and ORIF.

Almost all patients received at least one aspect of fracture management, with 98% receiving prophylactic antibiotics, 68% undergoing ORIF, 67% undergoing irrigation without debridement, and 23% undergoing I&D. Among those receiving each type of fracture management, approximately half or more received early treatment, ranging from 47% for early I&D to 78% for early irrigation without debridement. When examining factors associated with early versus delayed treatment, consistent with previous findings,[7–14] there were associations between serious non-facial injuries and delays in open facial fracture management: patients with serious head injury or moderate/severe TBI were more likely to receive delayed I&D, irrigation without debridement, and ORIF. It is possible that in these patients, emergency triage or surgical intervention for the serious head injury took precedence over open facial fracture management. Additionally, going directly from the ED to the OR was not associated with early surgical fracture management (I&D or ORIF), but going to the OR within 24 hours of arrival was; this again may suggest that immediate surgeries focused on emergency triage and that fracture management was addressed during later returns to the OR.

Although the descriptive data do not suggest that higher rates of infection were present among patients with delayed fracture management, a higher percentage of patients with markers of severe open facial fractures developed infection. Consistent with previous studies in open lower extremity fractures,[37–39] a higher percentage of patients with infection had type IIIc open fractures compared with those without infection; type IIIc fractures are characterized by extensive soft-tissue laceration, lengthy open-wound time prior to treatment, a high degree of contamination (eg, farm injuries), and arterial injuries requiring repair.[40] Although compared with patients without infection, a higher percentage of patients with infection underwent two or more debridements and fracture stabilizations, these percentages likely reflect a greater extent of injury among the patients with infection. Unlike some open extremity injuries with poor blood supply, open facial fractures tend to have excellent blood supply, which may have mitigated infection risk and may perhaps account for the overall low rate of infection in this large study population. Future studies should aim to continue investigating the effect of multiple aspects of open facial fracture management, including medical and surgical methods, on infection with larger sample sizes and increased power to conduct more complex analyses.

A potential limitation of the study was the definition of infection used. There is currently no standardized method of diagnosing open fracture wound infection,[41–43] and this study used a combination of a complication of infection recorded in the trauma registry, which required certain signs and symptoms to have been documented in the patient's electronic medical record (including positive bacterial culture at the open fracture site, purulent drainage from the incision, wound dehiscence, fever>38°C, localized pain/tenderness, or abscess at the wound site), as well as a diagnosis of infection documented in the chart by the patient's physician. However, it is possible that this set of criteria led to either overestimation or underestimation of the infection rate, which was quite low in this patient population (4%). This low infection rate also precluded analyses beyond descriptions of infection rates by treatment and open facial fracture variables, with no ability to draw definitive conclusions or conduct adjusted analyses. However, including five trauma centers across multiple states allowed for examination of a wide range of fracture management practices.

In this study, which hypothesized that non-facial injuries would be associated with delayed facial fracture management and investigated multiple facets of open facial fracture management—prophylactic antibiotics, I&D, irrigation without debridement, and ORIF—serious injuries to non-facial regions led to delays in surgical but not medical fracture management, likely because facial fracture management was lower priority than other emergency treatments and/or stabilization efforts. However, in most cases, if the patient went to the OR within 24 hours of hospital arrival for any reason, facial fracture management was undertaken during that trip. This study is unique in investigating factors associated with delays in both medical and surgical open facial fracture management, reporting on a large spectrum of fracture management in patients with open facial fractures.

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Patient consent for publication Not applicable.

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Data availability statement Data are available upon reasonable request. Deidentified analysis data sets are available in a limited form, per IRB requirements, upon reasonable request to the corresponding author.

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