Outcome differences in adolescent blunt severe polytrauma patients managed at pediatric versus adult trauma centers

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BACKGROUND: Previous research suggests adolescent trauma patients can be managed equally effectively at pediatric and adult trauma centers. We sought to determine whether this association would be upheld for adolescent severe polytrauma patients. We hypothesized that no difference in adjusted outcomes would be observed between pediatric trauma centers (PTCs) and adult trauma centers (ATCs) for this population.

METHODS: All severely injured adolescent (aged 12–17 years) polytrauma patients were extracted from the Pennsylvania Trauma Outcomes Study database from 2003 to 2015. Polytrauma was defined as an Abbreviated Injury Scale (AIS) score ≥3 for two or more AIS-defined body regions. Dead on arrival, transfer, and penetrating trauma patients were excluded from analysis. ATC were defined as adult-only centers, whereas standalone pediatric hospitals and adult centers with pediatric affiliation were considered PTC. Multilevel mixed-effects logistic regression models assessed the adjusted impact of center type on mortality and total complications while controlling for age, shock index, Injury Severity Score, Glasgow Coma Scale motor score, trauma center level, case volume, and injury year. A generalized linear mixed model characterized functional status at discharge (FSD) while controlling for the same variables.

RESULTS: A total of 1,606 patients met inclusion criteria (PTC: 868 [54.1%]; ATC: 738 [45.9%]), 139 (8.66%) of which died in-hospital. No significant difference in mortality (adjusted odds ratio [AOR]: 1.10, 95% CI 0.54–2.24; $p = 0.794$; area under the receiver operating characteristic: 0.89) was observed between designations in adjusted analysis; however, FSD (AOR: 0.38, 95% CI 0.15–0.97; $p = 0.043$) was found to be lower and total complication trends higher (AOR: 1.78, 95% CI 0.98–3.32; $p = 0.058$) at PTC for adolescent polytrauma patients.

CONCLUSION: Contrary to existing literature on adolescent trauma patients, our results suggest patients aged 12–17 presenting with polytrauma may experience improved overall outcomes when managed at adult compared to pediatric trauma centers. (*J Trauma Acute Care Surg.* 2017;83: 1082–1087. Copyright © 2017 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Epidemiologic study, level III.

KEY WORDS: Adolescent; polytrauma; outcomes; pediatric trauma center; adult trauma center.

The appropriate managing facility for pediatric, particularly adolescent, trauma patients is controversial. Although conflicting literature is present regarding total pediatric populations,[1–10] the vast majority of research comparing adolescent management at pediatric and adult trauma centers suggest these patients experience similar outcomes at either facility type.[6,7,11] Upon review of total adolescent trauma populations, both Matsushima et al.[6] and Walther et al.[7] found no difference in risk-adjusted outcomes for adolescent patients treated at pediatric or adult trauma centers. More recently, work by Gross et al.[11] analyzing a subgroup of adolescent isolated severe traumatic brain injury patients reported similar trends, with no differences in in-hospital mortality, complications, or functional discharge status observable between center types. Only one study was identified, by Webman and colleagues,[12] which reported improved outcomes for adolescent trauma patients when managed at pediatric trauma centers.

Although literature attempting to elucidate the optimal managing facility for adolescent trauma patients has produced relatively congruent findings, discussions of these works suggest further insight into differing injury categories and severity groupings is necessary. The purpose of this investigation was to further add to the literature on this underrepresented facet of the debate by comparing risk-adjusted outcomes at pediatric and adult trauma centers for adolescent patients presenting with severe polytrauma. Based on the majority of results from previous research investigating adolescent outcomes,[6,7,11] we hypothesized that severe polytrauma patients would have similar adjusted mortality, complications, and functional status at discharge when managed at pediatric and adult trauma centers.

METHODS

The Pennsylvania Trauma Outcome Study (PTOS) database was retrospectively queried for all adolescent trauma patients (aged 12–17 years) managed at Level I–II trauma centers in Pennsylvania from 2003 to 2015. PTOS is the statewide trauma registry of the Pennsylvania Trauma Systems Foundation—the accrediting body for trauma centers within the Commonwealth

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of Pennsylvania. To remain an accredited institution, trained registrars from the 38 Level I–IV trauma centers throughout the state are required to extract and submit de-identified hospital data to PTOS for all patients meeting specified trauma criteria. For the purpose of this study, the specific population of interest included all adolescent patients presenting with severe polytrauma (two or more Abbreviated Injury Scale [AIS]-defined body region scores ≥3). Dead on arrival, transfer, and penetrating trauma patients were excluded from analysis as to compare only patients with blunt injuries treated exclusively at one facility type.

To evaluate the impact of trauma center designation on adolescent polytrauma outcomes, the study population was separated into two groups: patients managed at pediatric trauma centers and patients managed at adult trauma centers. Pediatric trauma centers were defined as all adult/pediatric affiliated centers as well as all standalone pediatric centers, whereas adult centers were classified as standalone adult facilities. Univariate analysis in the form of Kruskal–Wallis tests for continuous variables and Fisher's exact tests for categorical variables was used to determine baseline demographic differences between patients managed at pediatric trauma centers (PTCs) and adult trauma centers (ATCs), as well as unadjusted outcome differences for mortality, complications, and functional status at discharge (FSD). Within the PTOS database, 48 complications are routinely collected from all trauma centers throughout the state. Incidence rates for each of these complications were extracted and reported for the total study population. FSD is a functional measure which assesses feeding, locomotion, expression, transfer mobility, and social interaction on a scale from 1 to 4 (1 = complete dependence; 4 = complete independence), no earlier than 48 hours pre-discharge.

Multilevel mixed-effects logistic regression models controlling for demographic and injury severity covariates were implemented to determine the adjusted impact of facility type

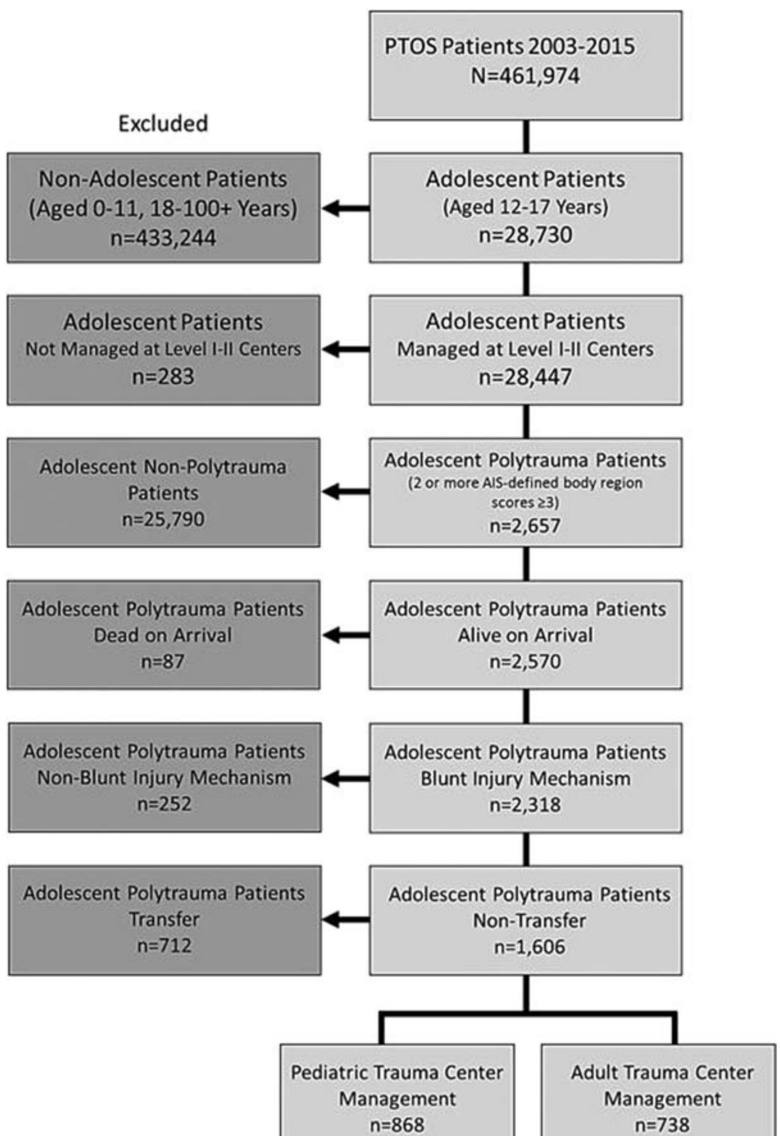

Figure 1. Flow diagram of total study population.

TABLE 1. Total Adolescent Polytrauma Study Population Demographics

Variable	Total Adolescent Population (n = 1,606)	Adult Trauma Center (ATC) (n = 738)	Pediatric Trauma Center (PTC) (n = 868)	*p**
Age, y, mean ± SD	15.5 ± 1.53	16.0 ± 1.23	15.2 ± 1.64	<0.001
Median (IQR)	16.0 (15.0–17.0)	16.0 (15.0–17.0)	15.0 (14.0–17.0)	
Gender, male, n (%)	1,078 (67.1)	495 (67.1)	583 (67.2)	0.969
Shock index, mean ± SD	0.85 ± 0.40	0.85 ± 0.44	0.85 ± 0.35	0.798
ISS, mean ± SD	30.4 ± 11.0	30.0 ± 10.8	30.9 ± 11.0	0.085
Median (IQR)	29.0 (22.0–28.0)	29.0 (22.0–36.5)	29.0 (22.0–38.0)	
GCS, mean ± SD	10.6 ± 5.38	10.6 ± 5.39	10.7 ± 5.36	0.658
Median (IQR)	14.0 (3.00–15.0)	14.0 (3.00–15.0)	15.0 (3.00–15.0)	
AIS scores, mean ± SD				
Median (IQR)				
Head	2.71 ± 1.79	2.64 ± 1.80	2.76 ± 1.77	0.170
	3.00 (1.00–4.00)	3.00 (1.00–4.00)	3.00 (2.00–4.00)	
Face	0.95 ± 0.96	0.92 ± 0.98	0.97 ± 0.94	0.347
	1.00 (0.00–2.00)	1.00 (0.00–2.00)	1.00 (0.00–2.00)	
Neck	0.09 ± 0.42	0.09 ± 0.44	0.09 ± 0.41	0.926
	0.00 (0.00–0.00)	0.00 (0.00–0.00)	0.00 (0.00–0.00)	
Thorax	2.47 ± 1.51	2.44 ± 1.51	2.49 ± 1.51	0.549
	3.00 (1.00–3.00)	3.00 (1.00–3.00)	3.00 (1.00–4.00)	
Abdomen	1.51 ± 1.65	1.52 ± 1.64	1.51 ± 1.66	0.882
	1.00 (0.00–3.00)	1.00 (0.00–3.00)	1.00 (0.00–3.00)	
Spine	0.82 ± 1.25	0.86 ± 1.27	0.79 ± 1.23	0.234
	0.00 (0.00–2.00)	0.00 (0.00–2.00)	1.00 (0.00–3.00)	
Upper extremity	1.12 ± 1.14	1.09 ± 1.16	1.15 ± 1.12	0.312
	1.00 (0.00–2.00)	1.00 (0.00–2.00)	0.00 (0.00–2.00)	
Lower extremity	1.63 ± 1.32	1.58 ± 1.34	1.67 ± 1.30	0.188
	2.00 (0.00–3.00)	2.00 (0.00–3.00)	2.00 (0.00–3.00)	
Facility case volume, mean ± SD	51.8 ± 36.2	33.6 ± 25.4	96.4 ± 69.4	0.029
ICU LoS, d ± SD	5.27 ± 8.24	5.11 ± 8.20	5.40 ± 8.28	0.480
Discharge destination				
Home	856 (53.3)	336 (45.5)	520 (59.9)	<0.001
Rehabilitation	515 (32.1)	262 (35.5)	253 (29.2)	0.065
Skilled nursing facility	11 (0.69)	3 (0.41)	8 (0.92)	0.213
Other	85 (5.29)	—	—	—
Missing	139 (8.66)	—	—	—
Complication, n (%)	385 (24.0)	177 (24.0)	208 (24.0)	0.992
Mortality, n (%)	139 (8.66)	74 (10.0)	65 (7.49)	0.075
FSD scores, mean ± SD	16.2 ± 4.57	16.3 ± 4.50	16.1 ± 4.63	0.589
Median (IQR)	18.0 (15.0–20.0)	18.0 (15.0–20.0)	18.0 (14.0–20.0)	
Feeding	3.41 ± 1.08	3.42 ± 1.05	3.41 ± 1.10	0.872
	4.00 (3.00–4.00)	4.00 (3.00–4.00)	4.00 (3.00–4.00)	
Locomotion	2.77 ± 1.15	2.81 ± 1.12	2.74 ± 1.17	0.323
	3.00 (2.00–4.00)	3.00 (2.00–4.00)	3.00 (2.00–4.00)	
Expression	3.55 ± 0.91	3.56 ± 0.94	3.53 ± 0.99	0.631
	4.00 (4.00–4.00)	4.00 (4.00–4.00)	4.00 (4.00–4.00)	
Transfer mobility	2.86 ± 1.13	2.82 ± 1.15	2.92 ± 1.09	0.121
	3.00 (2.00–4.00)	3.00 (2.00–4.00)	3.00 (2.00–4.00)	
Social interaction	3.52 ± 1.00	3.54 ± 0.97	3.51 ± 1.02	0.578
	4.00 (4.00–4.00)	4.00 (4.00–4.00)	4.00 (4.00–4.00)	
Missing, n (%)	401 (25.0%)	—	—	—

**p* values comparing ATC and PTC measures.
AIS, Abbreviated Injury Scale; FSD, functional status at discharge; GCS, Glasgow Coma Scale; IQR, Interquartile Range; ISS, Injury Severity Score; LoS, Length of Stay.

(PTC) on mortality and total complications. To determine the discrimination of the multilevel models, the area under the receiver operating characteristic (AUROC) was calculated. A generalized linear mixed model assessed the adjusted impact of facility type on FSD score within these two groups. All data manipulation and statistical analysis was performed using Stata/MP, version 14.1. Statistical significance was set at p <0.05.

RESULTS

A total of 1,606 patients met inclusion criteria. Within this population, 54% of patients were managed at PTC (n = 868) and 46% were managed at ATC (n = 738) (Fig. 1). Overall mortality rate was 9% (n = 139/1,606). A complete breakdown of study population demographics and univariate comparisons between PTC and ATC populations is presented in Table 1. No significant differences in Injury Severity Score (ISS), shock index, Glasgow Coma Scale score, or gender distribution were observed between center types; however, PTCs were found to manage significantly younger polytrauma patients on average (PTC: 16.0 ± 1.23, ATC: 15.2 ± 1.64; $p \leq 0.001$). In addition, pediatric centers were found to treat significantly larger volumes of adolescent polytrauma patients from on average during the study period (PTC: 96.4 ± 69.4 average cases per center 2003–2015, ATC: 33.6 ± 25.4 average cases per center; $p = 0.029$).

In terms of univariate analysis, no significant differences in unadjusted outcome measures were found between center types for FSD (PTC: 16.1 ± 4.63, ATC: 16.3 ± 4.50; $p = 0.589$) or total complication rate (PTC: 2.4%, ATC: 2.4%; $p = 0.992$). A complete listing of all PTOS-collected complications and the respective incidence of each complication within the study population is presented in Table 2. The most common complication among the adolescent study population was pneumonia (7.7%), followed by urinary tract infection (4.6%) and deep vein thrombosis (3.5%). Of patients experiencing a complication during their hospital stay (n = 385; 24.0%), the majority had only one identified complication (n = 202; 52.5%). A total of 183 patients experienced greater than one complication during their stay (47.5% of patients with complications). With respect to mortality, a trend toward improved mortality rate was observed at PTCs, however (PTC: 7.5%, ATC: 10.0%; $p = 0.075$). Compared to ATCs, PTCs were significantly more likely to discharge patients to home (PTC: 59.9%, ATC: 45.5%; $p < 0.001$; Table 1).

While controlling for age, shock index, ISS, GCS motor, trauma center level, case volume, and injury year, no significant difference in adjusted mortality was found between PTC and ATC for adolescent polytrauma patients in multilevel analysis (AOR: 1.10, 95% CI: 0.54–2.24; $p = 0.794$); however, a nonsignificant trend toward increased adjusted complications was observed (AOR: 1.78, 95% CI: 0.98–3.23; $p = 0.058$). Adjusted FSD was found to be significantly lower at PTCs compared to ATCs (AOR: 0.38, 95% CI: 0.15–0.97; $p = 0.043$). Overall, both the mortality model (AUROC: 0.89) and the complications model (AUROC: 0.78) were found to have good discrimination (Table 3).

TABLE 2. Breakdown of Collected Complications and Study Population Incidence Rates

Complication	n (%)
Acute arterial occlusion	3 (0.2)
Acute renal failure	9 (0.6)
Acute respiratory failure	21 (1.3)
Acute sinusitis	16 (1.0)
Adverse drug reaction	3 (0.2)
ARDS	20 (1.3)
Aspiration/aspiration pneumonia	24 (1.5)
Atelectasis	23 (1.4)
Blood transfusion reaction	4 (0.3)
Cardiopulmonary arrest (unexpected not resulting in death)	11 (0.7)
Central nervous system infection	9 (0.6)
Coagulopathy	38 (2.4)
Decubitus ulcer	51 (3.2)
Dehiscence/evisceration	4 (0.3)
Drug/alcohol withdrawal syndrome	0 (0.0)
Deep vein thrombosis	56 (3.5)
Empyema	1 (0.1)
Esophageal intubation	1 (0.1)
Extremity compartment syndrome	17 (1.1)
Fat embolus syndrome	5 (0.3)
Gastrointestinal bleeding	2 (0.1)
Hypothermia	10 (0.6)
Hypovolemia	0 (0.0)
Iatrogenic organ, nerve, vessel	12 (0.8)
Iatrogenic pneumothorax	28 (1.7)
Liver failure	2 (0.1)
Major dysrhythmia	13 (0.8)
Myocardial infarction	1 (0.1)
Nontraumatic evisceration	1 (0.1)
Pancreatitis	15 (0.9)
Pleural effusion	18 (1.1)
Pneumonia	124 (7.7)
Postoperative hemorrhage	3 (0.2)
Progression of original neurologic insult	9 (0.6)
Pulmonary embolism	7 (0.4)
Seizures	9 (0.6)
Sepsis	16 (1.0)
Septicemia	27 (1.7)
Small bowel obstruction	2 (0.1)
Soft tissue infection	10 (0.6)
Stroke/cerebrovascular accident	0 (0.0)
Unplanned intubation	4 (0.3)
Unplanned return to ICU	4 (0.3)
Unplanned return to OR	8 (0.5)
Unrecognized mainstem bronchus intubation	3 (0.2)
Urinary tract infection	73 (4.6)
Wound infection (traumatic/incisional)	29 (1.8)

ARDS, adult respiratory distress syndrome.

DISCUSSION

The objective of this investigation was to examine the impact of managing facility type on severely injured adolescent polytrauma patient outcomes. Although the results of this piece are in keeping with the majority of previous works analyzing adolescent outcomes in terms of adjusted mortality and complications,[6,11] the improved function observed at adult centers in this study are an unexpected finding. Viewing the results of this

TABLE 3. Adjusted Odds Ratios (AORs) for Adolescent Polytrauma Outcomes

	Mortality		FSD		Complications	
Variable	**AOR (95% CI)**	***p***	**AOR (95% CI)**	***p***	**AOR (95% CI)**	***p***
PTC	1.10 (0.54–2.24)	0.794	0.38 (0.15–0.97)	0.043	1.78 (0.98–3.23)	0.058
Age	1.04 (0.89–1.20)	0.639	0.88 (0.76–1.03)	0.114	1.17 (1.06–1.29)	0.002
Shock index	2.32 (1.49–3.60)	<0.001	0.71 (0.40–1.28)	0.258	1.32 (0.96–1.81)	0.084
ISS	1.07 (1.03–1.12)	<0.001	0.92 (0.89–0.94)	<0.001	1.06 (1.04–1.08)	<0.001
GCS motor	0.55 (0.48–0.63)	<0.001	2.69 (2.39–2.97)	<0.001	0.79 (0.74–0.84)	<0.001
TC level (Level I)	0.63 (0.36–1.11)	0.113	2.05 (0.93–4.53)	0.074	1.40 (0.83–2.39)	0.211
Case volume	0.99 (0.99–1.00)	0.216	1.01 (1.00–1.02)	0.090	0.99 (0.98–1.00)	0.001
Injury year	1.03 (0.97–1.10)	0.269	0.94 (0.89–0.99)	0.053	1.00 (0.96–1.05)	0.771
	AUROC: 0.89				AUROC: 0.78	

AUROC, area under the receiver operating characteristic; FSD, functional status at discharge; GCS, Glasgow Coma Scale; ISS, Injury Severity Score; PTC, pediatric trauma center.

investigation in composite, our hypothesis is upheld with respect to similar mortality and complications between pediatric and adult centers, but refuted in terms of functional status at discharge.

Based on the results of univariate comparisons between PTC and ATC facility populations, it is not surprising that adjusted differences in mortality and complications failed to reach conventional levels of statistical significance. Both pediatric and adult centers managed polytrauma patients with statistically similar injury severity measures and gender distributions, with age being the only patient demographic factor to elicit significant differences between facility types. These univariate comparisons vary slightly from the work of Matsushima et al.,[6] Walther et al.,[7] and Webman et al.[12] who reported both significantly older and more severely injured populations at adult centers. The fact that our study was restricted to patients presenting with severe polytrauma (two or more AIS scores ≥3) could explain some of the unadjusted severity similarities between our PTC and ATC populations. Despite the injury severity discrepancies in the literature, Webman and colleagues were the only group able to associate improved outcomes for adolescent patients at pediatric centers, with an incredible 661% increased odds ratio for in-hospital mortality observed at adult sites. Although Webman et al. were the first to investigate this question within a national dataset (the National Trauma Data Bank), it is important to note that discrepancies between data sources and the variability in practice patterns across multiple states likely resulted in the differences observed between this work and the mature state analyses by Matsushima et al. and Walther et al.

All things being equal, the fact that functional outcomes were significantly lower at pediatric centers suggests differences in management approaches and/or practice patterns between pediatric and adult centers are a possible cause of this trend. Although pediatric centers experience greater volumes of adolescent polytrauma, when viewing overall trauma volume, adult centers manage a greater caseload. Caring for greater quantities of patients, it is possible individuals managed at adult centers experience more streamlined care, particularly pertaining to in-hospital physical therapy and rehabilitative services—a factor that could have a profound impact on improving function at discharge. In addition to these explanations, it is also possible our analysis failed to control for confounding factors, which could influence functional outcome. Although pediatric centers typically receive large quantities of transfer patients, essentially delaying these patients' time to definitive care, the fact that we excluded these cases from analysis eliminates this potentially confounding variable from effecting our outcome measures. In addition, upon review of Table 1 and intensive care unit (ICU) length of stay comparisons, it also becomes apparent that pediatric and adult centers in Pennsylvania were keeping patients for similar periods of time from 2003 to 2015, thus eliminating this factor as a potential explanation for functional discrepancies between sites.

This study is not without its limitations. In addition to the inherent threats to validity present in any retrospective analysis, the results of this piece only include one state trauma system and, as such, most likely lack generalizability to the adolescent polytrauma population at large. It is also important to note that although four studies have examined adolescent outcomes at pediatric and adult trauma centers, 75% of these works have examined the same statewide trauma registry, further muddling the combined impact of these works. Finally, although this study attempted to analyze an array of outcomes pertaining to the adolescent population, we realize these measures fail to provide a complete view of differences between center types. Assessment of mortality and functionality 30 days and 6 months post-discharge would likely be more useful outcome indicators. Unfortunately, data on these measures are not available within the Pennsylvania Trauma Outcome Study database.

CONCLUSION

The appropriate managing facility for adolescent trauma patients is debatable. The results of this investigation suggest adolescent severe polytrauma patients have similar adjusted mortality and complications when managed at pediatric and adult centers; however, experience improved functional discharge status at adult institutions. Based on the overwhelming similarities in research findings for adolescent patients, designating authorities like the Pennsylvania Trauma Systems Foundation and the American College of Surgeons should re-examine admission criteria and mandatory transfer protocols for adolescents.

AUTHORSHIP

A.T.R.—study design, data collection, data analysis, interpretation of data, article preparation. B.W.G.—study design, data collection, data analysis, interpretation of data, article preparation, editorial oversight. A.D.C.—study design, data analysis, interpretation of data, article preparation. C.D.R.—data analysis, interpretation of data, article preparation. C.A.L.—data analysis, interpretation of data, article preparation. E.H.B.—data analysis, interpretation of data, article preparation. C.C.H.—interpretation of data, article preparation, editorial oversight. F.B.R.—study design, interpretation of data, article preparation, editorial oversight.

DISCLOSURE

All authors have neither conflicts of interest nor disclosures of funding to declare.

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