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ORIGINAL CONTRIBUTIONS

Adolescent Bariatric Surgery: Effects of Socioeconomic, Demographic, and Hospital Characteristics on Cost, Length of Stay, and Type of Procedure Performed

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Abstract

Background Despite the efficacy of bariatric surgery in adolescents and the increasing rates of adolescent obesity, the use of bariatric surgery remains low. Treatment cost and length of stay (LOS) could be influencing the utilization of bariatric surgery.

Methods We used the Kids' Inpatient Database (KID) from 2006, 2009, and 2012. Adolescents with a primary diagnosis of obesity who underwent bariatric surgery were included. Multinomial logistic and linear regression modeling was used to determine the association of the predictor variables with type of procedure and treatment cost and LOS, respectively.

Results We identified 1799 adolescents who underwent bariatric surgery. The majority of the subjects were female (77%) and White (60%). The most commonly performed procedure was Roux-en-Y gastric bypass (56%). Race, region, hospital teaching status, and hospital ownership affected the type of procedure performed. Self-pay patients were less likely to undergo Roux-en-Y gastric bypass (RYGB) than sleeve gastrectomy (SG) when compared to patients with private insurance. Teaching hospitals were less likely to perform RYGB or AGB than SG when compared to non-teaching hospitals. Treatment cost was significantly affected by income, teaching hospital status, hospital size, and surgery type. LOS was affected by income quartile, region, and surgery type.

Conclusion Socioeconomic and demographic factors as well as hospital characteristics affect not only the LOS and treatment cost, but also the type of bariatric surgery performed in adolescents. Identifying and understanding the factors influencing procedure choice, treatment cost, and LOS can improve care and healthcare resource utilization.

Keywords Bariatric surgery · Adolescent obesity · Childhood obesity · Length of stay · Treatment cost

Introduction

Childhood obesity is a major health issue in the twenty-first century. From 1999 to 2016, the prevalence of obesity has significantly increased in both adults and children; 18.5% of youth aged 2 to 19 are obese with the highest rates observed among adolescents aged 12–19 years at 21% [1]. The rising prevalence and severity of childhood obesity have led to an increase in several severe obesity-related conditions (ORCs), including non-alcoholic fatty liver disease, colon cancer, diabetes, hypertension, and cardiovascular disease [2–7]. Perhaps, the most important sequela of childhood obesity is its propensity to result in adult obesity. Most obese adults were overweight or obese as adolescents, and most obese adolescents were overweight or obese as children [8].

Dietary, activity-based, and behavioral interventions are the first-line treatment for obesity in adolescents. However, the weight loss from these interventions is usually more effective in the short term than in the long term [9]. A recent Cochrane review found a maximum of 1.7 kg/m^2 reduction in BMI after 1 year of lifestyle modification compared to a reduction of up to 13.2 kg/m^2 after bariatric surgery [10, 11]. In addition, the prospective multicenter Teen-LABS study has demonstrated a significant decrease in weight and BMI in

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adolescents who underwent bariatric surgery when compared to those who underwent lifestyle modifications at 6- and 12-month follow-up with good 3-year outcomes [12, 13].

Despite the evidence supporting the efficacy of bariatric surgery in the adolescent population, it remains underutilized. Bariatric surgery in adolescents increased by almost 50-fold from 1996 to 2003, but has now plateaued [14, 15]. Only approximately 1600 bariatric procedures were performed on adolescents in 2009, well below the eight million adolescents who could qualify for bariatric surgery [15–17]. There is a growing interest in the development of adolescent bariatric treatment programs [18], indicating that if the factors that are contributing to the underutilization of bariatric surgery could be identified, these numbers could potentially be increased.

Bariatric surgery procedures have evolved over time. Adjustable gastric banding (AGB) was historically the most common surgery performed, but long-term outcomes have favored Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy (SG) [19, 20]. Since the mid-2000s, the most common bariatric surgery utilized in adults has been SG [20]. SG is less time-consuming and less technically challenging and is associated with fewer complications when compared to RYGB [19]. AGB has fallen out of favor due to its decreased efficacy and high complication rate [21, 22].

Our group has previously published that minority adolescents undergo bariatric surgery at lower-than-expected rates [23]. Cost, length of stay (LOS), and type of procedure performed could all be contributing to the underutilization of bariatric surgery in adolescents; though, additional factors may also be playing a role. In the adult population, only 46.5% of primary care physicians feel comfortable providing care to patients who have had bariatric surgery and 70.2% of primary care physicians refer no more than 5% of their obese population for surgery [24]. Psychosocial factors can significantly influence the adherence to treatment guidelines and outcomes in adult bariatric patients [25–27] and likely influence adolescents as well. Family dynamics are an important part of adolescent care, as children with impaired family functioning reported having less support for successfully implementing diet and exercise changes [28]. (Reviewer #2) Further analysis is necessary to understand the factors that could be contributing to the underutilization of bariatric surgery overall, as well as in different demographic populations. To accomplish this, we conducted a multivariable linear regression model using the Kids' Inpatient Database to analyze the factors influencing cost, LOS, and type of procedure performed.

Methods

Study Design and Data Source

A retrospective cross-sectional study was conducted using the most recently available data from the Kids' Inpatient Database, a national database published by the Agency for Healthcare Research and Quality under the Healthcare Cost and Utilization Project. This database is published every 3 years and is the largest publicly available pediatric inpatient care database, encompassing 4000 hospitals across 38–44 states in the USA. The years 2006, 2009, and 2012 were used for this analysis. National estimates were made by using discharge weights from the American Hospital Association.

Study Population

Of all pediatric discharges, adolescents aged 12–19 who had bariatric surgery were identified using the following ICD-9-CM codes: 44.68 (gastric restrictive procedure, vertical-banded gastroplasty), 44.69 (gastric restrictive procedure, other than vertical-banded gastroplasty), 44.39 (RYGB), 44.38 (laparoscopic RYGB), 43.89 (laparoscopic sleeve gastrectomy), and 44.95 (implantation of adjustable gastric band and port).

Patient Characteristics

Patient characteristics included race, gender, primary payer, median household income, and procedure type. Race was self-reported and categorized as Black, Hispanic, White, or other. Primary payer was categorized as self-pay, Medicaid, private, or other. Median household income was categorized into quartiles by ZIP codes, with Q1 representing the lowest income quartile and Q4 representing the highest income quartile. Quartiles were used because monetary value changes over the reported years, as a result of inflation.

Hospital Characteristics

Hospital characteristics included teaching status, ownership, size, and region. Teaching status was considered to be teaching or non-teaching. Ownership was categorized as government-owned or private. Government-owned hospitals have non-federal funding, and privately owned hospitals included those which are not-for-profit and those which are investor-owned. Hospital size was characterized as small, medium, or large using the number of beds and stratified by teaching status and region. Regions were categorized as Northeast, Midwest, South, and West.

Outcome Variables

The following outcomes were considered: length of stay (LOS) and total costs. Cost was converted from hospital charges using the HCUP Cost-to-Charge Ratio. All costs were converted to 2012 US dollars using the consumer price index.

Statistical Analysis

All statistical analyses accounted for the complex survey design, enabling an unbiased variance of national estimates. Patient-level analyses included discharge weight, hospital clustering, hospital stratification, and domain information [29]. This accounts for hierarchical structure of our data; patients nested within hospital. To determine the association of patient- and hospital-level characteristics with various outcomes, multivariable models were fit: logistic regression for in-hospital mortality and linear regression for hospital length of stay and total cost during hospitalization. All the statistical analyses were performed using SAS 9.4 (SAS Institute Inc., Cary, NC), with two-sided tailed tests. The level of significance (α) was set at 0.05.

Results

Patient Characteristics

Table 1 shows the characteristics of our cohort. We identified 2657 adolescents who underwent bariatric surgery during the study period. The plurality of subjects were female (77%, $n = 2036$). The mean age of procedure was 18 ± 1.2 years. Whites represented 60% ($n = 1604$), Hispanics 20% ($n = 522$), Blacks 13% ($n = 343$), and other 7% ($n = 188$). The most commonly performed procedure was RYGB (56%, $n = 1474$), followed by SG (23%, $n = 617$) and AGB (21%, $n = 565$).

The primary payer was largely private insurance (66%, $n = 1748$), followed by Medicaid (16%, $n = 431$), self-pay (11%, $n = 298$), and other (7%, $n = 180$). The majority of subjects (61%, $n = 1594$) received surgical care in a large bed-size hospital. Examination by hospital teaching status demonstrated that most were classified as teaching hospitals (57%, $n = 1505$) and as private (58%, $n = 1490$).

Type of Bariatric Procedure

Several sociodemographic characteristics were associated with specific types of bariatric procedures (Table 2). Using SG as reference procedure, Hispanics were less likely to undergo AGB (OR 0.50, 95% CI 0.30–0.84) compared to Whites. Self-pay patients were less likely to undergo RYGB (OR 0.47, 95% CI 0.31–0.73) than those with private insurance, whereas patients classified as other payer types were more likely to undergo AGB (OR 10.13. 95% 3.57–28.74) and RYGB (OR 6.00, 95% CI 2.43–14.86) than those with private insurance.

Hospital characteristics and geographic regions were also associated with specific types of bariatric procedures (Table 2). Teaching hospitals were less likely to perform RYGB (OR 0.35, 95% CI 0.22–0.56) and AGB (OR 0.42, 95% CI 0.24–0.75) than SG. Government-owned hospitals were more likely to perform RYGB (OR 7.67, 95% CI 4.43–13.28) and AGB (OR 14.94, 95% CI 8.26–27.01). Hospitals located in the Midwest and South were less likely to perform RYGB (OR 0.24, 95% CI 0.12–0.48, and OR 0.43, 95% CI 0.26–0.73, respectively) and AGB (0.14, 95% CI 0.05–0.37, and 0.36, 95% CI 0.19–0.69, respectively) when compared to hospitals in the West.

Table 1 Demographics—weighted

Patient characteristics	*N* (%)
Total patients	2657 (100)
Sex	
Female	2036 (77)
Male	620 (23)
Race	
White	1604 (60)
Black	343 (13)
Hispanic	521 (20)
Other	188 (7)
Type of surgery	
Roux-en-Y gastric bypass (RYGB)	1474 (55)
Sleeve gastrectomy (SG)	617 (23)
Adjustable gastric banding (AGB)	565 (21)
Median ZIP code income quartile	
First	647 (24)
Second	546 (21)
Third	687 (26)
Fourth	777 (29)
Primary payer	
Medicaid	431 (16)
Private	1748 (66)
Self-pay	298 (11)
Other	180 (7)
Geographic region	
Northeast	833 (31)
Midwest	261 (10)
South	1102 (41)
West	460 (17)
Hospital teaching status	
Teaching	1505 (57)
Non-teaching	1151 (43)
Hospital ownership	
Government	1167 (44)
Private	1490 (56)
Hospital size	
Small	408 (15)
Medium	655 (25)
Large	1594 (60)

Table 2 Odds ratio compared to sleeve gastrectomy

	Roux-en-Y gastric bypass OR (95% CI)	Adjustable gastric banding OR (95% CI)
Race (reference—White)		
Black	1.06 (0.70–1.60)	1.12 (0.67–1.87)
Hispanic	0.73 (0.50–1.06)	*0.50 (0.30–0.84)*
Other	0.74 (0.44–1.25)	0.60 (0.31–1.18)
Sex (reference—male)		
Female	1.24 (0.92–1.67)	0.97 (0.68–1.37)
Primary payer (reference—private)		
Medicaid	1.22 (0.80–1.86)	1.21 (0.70–2.09)
Self-pay	*0.47 (0.31–0.73)*	0.71 (0.40–1.28)
Other	*6.00 (2.43–14.86)*	*10.13 (3.57–28.74)*
Income quartile (reference—Q4)		
Q1	1.34 (0.90–2.01)	1.56 (0.94–2.57)
Q2	*1.55 (1.041–2.29)*	1.28 (0.75–2.17)
Q3	1.25 (0.875–1.79)	1.11 (0.72–1.70)
Teaching hospital status (reference—non-teaching)		
Teaching	*0.35 (0.22–0.56)*	*0.42 (0.24–0.75)*
Hospital ownership (reference—private)		
Government	*7.67 (4.43–13.28)*	*14.94 (8.26–27.01)*
Hospital size (reference—small)		
Medium	1.56 (0.85–2.88)	0.69 (0.30–1.59)
Large	1.59 (0.89–2.87)	0.99 (0.45–2.18)
Hospital region (reference—West)		
Northeast	0.55 (0.29–1.05)	1.13 (0.55–2.32)
Midwest	*0.24 (0.12–0.48)*	*0.14 (0.05–0.37)*
South	*0.43 (0.26–0.73)*	*0.36 (0.19–0.69)*

The italicized values represent findings that are statistically significant; that is an odds ratio that does not include 1 or a p value <0.05

Length of Stay

Income quartile, hospital region, and surgery type all significantly affected the LOS (Table 3). Patients in the first quartile had a significantly lower LOS when compared to those in the fourth quartile (− 0.29 days, $p = 0.01$). Patients in the Midwest had a significantly longer LOS than those treated in the West (+ 0.63 days, $p = 0.005$). LOS was not significantly affected by race, sex, primary payer, hospital size, hospital teaching status, or hospital ownership.

Compared to SG, adolescents who underwent RYGB had a longer LOS (+ 0.45 days, $p = 0.0005$) while those who underwent AGB had a shorter LOS (− 0.73 days, $p < 0.0001$).

Treatment Cost

Treatment cost was significantly affected by income quartile, teaching hospital status, hospital size, and surgery type (Table 4). Patients whose median household income was in the lowest quartiles had less expensive care than those in the highest quartile (− $2034, $p = 0.0006$, and − $1672, $p = 0.005$, respectively). Large and medium hospitals had less expensive care compared to small hospitals (− $3574, $p = 0.006$, and − $2977, $p = 0.05$, respectively). Treatment cost was also lower in teaching hospitals than in non-teaching hospitals (− $2032, $p = 0.003$). AGB was associated with significantly less expensive care than SG (− $3065, $p = 0.001$).

After stratification by surgery type, several additional factors contributing to treatment cost emerged (Table 5). AGB was less expensive for female patients than for male patients (− $1460, $p = 0.04$). RYGB had a significantly lower treatment cost for patients in the lowest income quartiles (− $3544, $p = 0.0003$, and − $2901, $p = 0.005$, respectively) than those in the highest quartile. SG at teaching hospitals was less expensive than at non-teaching hospitals (− $3410,

Table 3 Length of stay stratified by socioeconomic and hospital characteristics

	Estimated change in length of stay (in days)	p value
Race (reference—White)		
Black	+ 0.16	0.26
Hispanic	+ 0.01	0.96
Other	− 0.17	0.16
Sex (reference—male)		
Female	− 0.24	0.09
Primary payer (reference—private)		
Medicaid	+ 0.18	0.18
Self-pay	+ 0.14	0.61
Other	− 0.16	0.29
Income quartile (reference—Q4)		
Q1	*− 0.29*	*0.01*
Q2	− 0.16	0.29
Q3	− 0.06	0.70
Teaching hospital status (reference—non-teaching)		
Teaching	− 0.16	0.14
Hospital ownership (reference—private)		
Government	+ 0.10	0.43
Hospital size (reference—small)		
Medium	+ 0.10	0.58
Large	+ 0.19	0.11
Hospital region (reference—West)		
Northeast	+ 0.33	0.09
Midwest	*+ 0.63*	*0.005*
South	+ 0.10	0.51
Surgery type (reference—sleeve gastrectomy)		
Roux-en-Y gastric bypass	*+ 0.45*	*0.0005*
Adjustable gastric banding	*− 0.73*	*< 0.0001*

The italicized values represent findings that are statistically significant; that is an odds ratio that does not include 1 or a p value <0.05

Table 4 Treatment cost stratified by socioeconomic and hospital characteristics

	Estimated change in cost (in USD)	*p* value
Race (reference—White)		
Black	+ 845.58	0.23
Hispanic	− $775.28	0.15
Other	+ $236.34	0.78
Sex (reference—male)		
Female	− $737.70	0.27
Primary payer (reference—private)		
Medicaid	+ $518.92	0.39
Self-pay	+ $923.00	0.55
Other	− $261.47	0.66
Income quartile (reference—Q4)		
Q1	*− $2033.98*	*0.0006*
Q2	*− $1672.36*	*0.005*
Q3	− $627.26	0.45
Teaching hospital status (reference—non-teaching) Teaching	*− $2031.58*	*0.003*
Hospital ownership (reference—private)		
Government	+ $378.11	0.61
Hospital size (reference—small)		
Medium	*− $3574.13*	*0.006*
Large	*− $2977.21*	*0.05*
Hospital region (reference—West)		
Northeast	− $880.78	0.49
Midwest	+ $2364.26	0.09
South	+ $120.00	0.91
Surgery type (reference—sleeve gastrectomy)		
Roux-en-Y gastric bypass	+ $501.11	0.57
Adjustable gastric banding	*− $3065.07*	*0.001*

The italicized values represent findings that are statistically significant; that is an odds ratio that does not include 1 or a *p* value <0.05

$p = 0.008$). When compared to small hospitals, AGB was less expensive at large hospitals (− $2918, $p = 0.03$), while SG was less expensive at medium and large hospitals (− $8876, $p = 0.0002$, and − $8927, $p = 0.0004$, respectively). RYGB and SG were both more expensive in the Midwest than in the West (+ $2895, $p = 0.05$, and + $4028, $p = 0.05$, respectively).

Discussion

Bariatric surgery in adolescents is an underutilized option, despite being established as effective in both weight loss and remission of ORCs [12, 13, 30]. Our identified sample is well below the estimated number of adolescents that potentially qualify for a weight loss procedure. By examining the sociodemographic and hospital characteristics that affect treatment cost and LOS, we have identified factors that could be influencing the type of procedure performed and the utilization of bariatric surgery in adolescents.

Though several studies have demonstrated the cost-effectiveness of bariatric surgery in adolescents [11, 16] as well as its safety and efficacy [13, 31], the number of these procedures has not increased proportionately with the increasing prevalence of adolescents who may qualify for these procedures. One reason cited for this imbalance is the resistance from primary payers to cover these surgeries [32]. Only 47% of adolescent patients obtain insurance approval on the first request, though 80% of those initially declined coverage are eventually approved [33]. Delay in surgical treatment has been linked to higher mortality and reduced survival in adults [32] and has been argued to do the same in adolescents [34]. Lowering hospital costs for adolescent bariatric surgery could encourage insurers to provide more timely approval for bariatric procedures and increase utilization.

Our results demonstrated decreased cost associated with income quartile, teaching hospital status, hospital size, and surgery type. Patients in the lowest two income quartiles had a decreased cost of surgery when compared to those in the highest income quartile. LOS was significantly decreased for those in the lowest income quartile, which could be contributing to the decreased cost. Interestingly, when stratified by surgery type, the only significant reduction in cost for those quartiles was for RYGB, although the reason for this needs further elucidation. In adults, cost of RYGB and SG linearly increased with LOS and almost doubled after 1 week [32]. While poverty is a significant predictor of non-insurance [35], our results demonstrated no difference in cost or LOS for different primary payers. Income also has a significant effect on whether children are enrolled in Medicaid fee-for-service or Medicaid comprehensive managed care [36], and may confound the results seen in children with Medicaid listed as the primary payer.

Teaching hospital status and larger hospital size were also significantly associated with lower treatment costs. However, when these results were stratified by surgery type, only SG showed a statistically significant treatment cost reduction. Teaching hospitals and large hospitals performed the majority of bariatric procedures in obese adolescents, and this may lead to better perioperative algorithms via minimization of resource utilization. Increased cost for RYGB and SG was seen in the Midwest, and only 10% of all adolescent bariatric surgery procedures were performed in that region, consistent with this theory. In other types of surgery, increased case volume has been linked to decreased total cost, decreased complications, and decreased length of stay [37–39]. In our results, LOS is not significantly affected by teaching hospital status or larger size. The typical LOS following bariatric surgery in adults is approximately 2 days, and the next-day discharges are common for both SG and AGB [32]. Since LOS is already low after bariatric surgery,

Table 5 Treatment cost stratified by surgery type

	Roux-en-Y gastric bypass		Adjustable gastric banding		Sleeve gastrectomy	
	Estimated change in cost (in 2012 USD)	*p* value	Estimated change in cost (in 2012 USD)	*p* value	Estimated change in cost (in 2012 USD)	*p* value
Race (reference—White)						
Black	+ $602.71	0.51	+ $857.12	0.46	+ $22,347.88	0.25
Hispanic	− $1018.03	0.10	+ $1119.42	0.93	− $1336.36	0.21
Other	− $172.20	0.88	+ $2271.84	0.04	− $295.02	0.85
Sex (reference—male)						
Female	− $662.83	0.55	*− $1460.22*	*0.04*	+ $231.94	0.80
Primary payer (reference—private)						
Medicaid	+ $1016.94	0.17	+ $1247.15	0.29	− $885.97	0.56
Self-pay	+ $1981.85	0.49	− $629.82	0.40	− $1024.09	0.53
Other	+ $186.60	0.83	− $879.81	0.24	+ $580.57	0.66
Income quartile (reference—Q4)						
Q1	*− $3543.61*	*0.0003*	− $784.11	0.29	− $584.20	0.64
Q2	*− $2900.60*	*0.005*	+ $1051.81	0.21	− $545.98	0.53
Q3	− $1430.14	0.30	+ $515.93	0.50	− $426.76	0.68
Teaching hospital status (reference—non-teaching)						
Teaching	− $1501.79	0.08	− $433.51	0.61	*− $3409.66*	*0.008*
Hospital ownership (reference—private)						
Government	− $100.41	0.91	+ $1646.23	0.16	− $894.78	0.58
Hospital size (reference—small)						
Medium	− $652.58	0.67	− $2148.31	0.13	*− $8875.55*	*0.0002*
Large	− $1398.99	0.20	*− $2918.10*	*0.03*	*− $8926.87*	*0.0004*
Hospital region (reference—West)						
Northeast	− $139.11	0.93	*− $5227.85*	*0.003*	− $413.74	0.81
Midwest	*+ $2895.47*	*0.05*	*− $4411.06*	*0.03*	*+ $4028.08*	*0.05*
South	+ 395.19	0.76	*− $3052.06*	*0.05*	+ 252.27	0.86

The italicized values represent findings that are statistically significant; that is an odds ratio that does not include 1 or a *p* value <0.05

statistically significant changes may be difficult to demonstrate. Further insight into the factors and practices which lower costs in these hospitals could lead to the development of protocols to lower costs at smaller, non-teaching hospitals.

We also identified several factors which influenced the type of bariatric surgery performed. Self-pay patients were less likely to undergo RYGB than SG. We demonstrated no difference in cost between SG and RYGB in the adolescent population, so the reasons for this are unclear. Teaching hospital status was associated with decreased likelihood of performing RYGB or AGB compared to SG. Notably, the opposite was seen in government-owned hospitals, and no significant difference was observed in large hospitals. The current literature promotes SG over AGB due to increased efficacy of SG and over RYGB since it is a simpler and faster procedure than RYGB [20]. Due to their teaching hospital status, increased emphasis may be placed on following evidence-based guidelines than in non-teaching hospitals. Hispanic patients were significantly less likely to receive AGB than SG, which may indicate that patients in this population are either more likely to go to teaching facilities or that sociodemographic factors are influencing their likelihood of undergoing SG. While studies in adults have demonstrated that Hispanic patients are less likely to undergo bariatric surgery, no significant difference in the type of procedure performed has been previously reported [40].

Limitations of this study are related to the use of a national database. No data is included on the preadmission or postoperative costs after discharge, which could affect the total expenses of bariatric surgery. In addition, the database relies on accurate and consistent data entry. Unfortunately, when using national databases, there is a limited amount of patient data available which limits our ability to analyze factors that are not recorded, such as emotional outcomes, family effects, and late

complications. It is possible that some of these factors could help explain some of the significant results we generated in this study (Reviewer #2). Despite these limitations, the use of national databases is essential in answering questions on a large scale that could lead to improvement of patient care and optimization of outcomes.

Conclusion

Multiple factors that significantly influence treatment cost, LOS, and type of bariatric procedure performed in adolescents have been identified. Further research directed at elucidating the direct effect these factors have on procedure choice, treatment cost, and LOS could help increase utilization of adolescent bariatric surgery and improve outcomes.

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Compliance with Ethical Standards

This study was considered non-human subjects research due to the use of nationally available de-identified data and, therefore, was deemed exempted by the institution's Institutional Review Board.

Conflict of Interest The authors declare that no conflicts of interest exist.

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