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Post-operative outcomes and anesthesia type in total hip arthroplasty in patients with obstructive sleep apnea: A retrospective analysis of the State Inpatient Databases

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THESE

préparée sous la direction du Professeur Eric Albrecht
avec la co-direction du Professeur Kane Pryor

et présentée à la Faculté de biologie et de médecine de
l'Université de Lausanne pour l'obtention du grade de

DOCTEUR EN MEDECINE

par

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Monsieur le Professeur John Prior
Vice-Directeur de l'Ecole doctorale

RESUME DE THESE

But de l'étude

Le but de cette étude était d'investiguer les résultats post opératoires après pose de prothèse totale de hanche (PTH) chez les patients atteints du syndrome d'apnée du sommeil (SAOS). Par ailleurs, nous avions pour but d'évaluer l'évolution du recours à l'anesthésie régionale (AR) versus l'anesthésie générale (AG) suite à la publication de recommandations pratiques en faveur de l'AR. Enfin, nous avions pour but de comparer les résultats post opératoires en fonction du type d'anesthésie employé.

Matériel et Méthode

Afin d'atteindre ces buts, nous avons mené une étude clinique rétrospective incluant 500'189 patients ayant subi une PTH dans les états américains de la Californie, la Floride, New York, le Maryland et le Kentucky entre 2007 et 2014, inclus dans une base de données d'État nommé State Inpatient Databases (SID), Healthcare Cost and Utilization Project. Parmi ces patients, 22'842 (4.6%) d'entre eux avaient un diagnostic de SAOS. L'effet du SAOS sur les résultats post-opératoires a été investigués à l'aide de modèles de régression logistique bi- et multivariées. Les résultats post-opératoires étudiés étaient la mortalité intra-hospitalière, les complications post-opératoires, la durée d'hospitalisation et le taux de réadmission. Dans un sous-groupe de population incluant des patients de l'État de New York uniquement (n=111'684 dont 5'464 patients avec un diagnostic de SAOS [4.9%]), nous avons investigué les résultats post-opératoires dans la population avec un diagnostic de SAOS en fonction du type d'anesthésie. L'ensemble des analyses ont été appliquées sur l'ensemble de la période d'étude ainsi que sur chaque année individuelle.

Résultats

La prévalence du SAOS a augmenté au cours de l'étude, passant de 1.7% en 2007 à 6.9% en 2014. En analyse multivariée, il n'y a pas d'effet du SOAS sur la mortalité intra-hospitalière. Le taux de complication postopératoire, la durée de l'hospitalisation et le taux de réadmission étaient supérieur chez les patients avec SAOS. Dans cette population, le taux de complications, en particulier d'origine pulmonaire était significativement plus élevé chez les patients ayant subi une AG comparé aux patients ayant subi une AR. Le taux de mortalité, de réadmission et la durée de l'hospitalisation n'étaient pas influencés par le type d'anesthésie. Le taux de PTH réalisées sous AG chez les patients avec SAOS était en augmentation sur la période de l'étude.

Conclusions

Notre étude met en évidence que la prévalence de SAOS est en forte augmentation, puisque qu'elle a quadruplé entre 2007 et 2014. Le SAOS est associé à un risque augmenté de complications post-opératoires, une durée d'hospitalisation prolongée, un risque augmenté de réadmission mais pas à un risque de mortalité post-opératoire augmenté. Le recours à l'AG chez les patients atteints de SAOS est associé à un risque augmenté de complications. En dépit de la publication de recommandations cliniques en faveur de l'utilisation de l'AR chez les patients avec SAOS, on note une augmentation du recours à l'AG au cours de la période d'étude.

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Original Contribution

Post-operative outcomes and anesthesia type in total hip arthroplasty in patients with obstructive sleep apnea: A retrospective analysis of the State Inpatient Databases

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ABSTRACT

Study objectives: To investigate postoperative outcomes following total hip arthroplasty (THA) in patients with obstructive sleep apnea (OSA). To evaluate trends in the use of regional anesthesia (RA) versus general anesthesia (GA) following the publication of practical guidelines. To compare postoperative outcomes according to anesthesia type.
Design: Retrospective analysis.
Setting: Operating room.
Patients: 349,008 patients who underwent elective THA in Florida, New York, Maryland, and Kentucky between 2007 and 2014 were extracted from the State Inpatient Databases (SID), Healthcare Cost and Utilization Project, including 18,063 patients with OSA (5.2%).
Interventions: No intervention.
Measurements: The effect of OSA on postoperative outcomes was investigated using bivariate analysis and multivariable logistic regression models. Outcomes studied included in-hospital mortality, postoperative complications, length of stay (LOS), and post-discharge readmissions. In a population from New York only, (n = 105,838 with 5306 patients with OSA [5.0%]), we investigated the outcomes in the OSA population according to the anesthesia type. Analysis was performed overall and for each individual year.
Main results: The OSA prevalence increased from 1.7% in 2007 to 7.1% in 2014. In multivariable analysis, there was no effect of OSA on in-hospital mortality (aOR:0.57; 0.31–1.04). Postoperative complications, LOS, and readmission rates were all higher in patients with OSA. In patients with OSA receiving GA than those receiving RA, we found a higher rate of complications overall and pulmonary complications specifically in men and higher rate of 90-day readmission in women. Over the study period, the rate of GA use in patients with OSA increased.
Conclusions: The OSA prevalence in patients undergoing THA increased fourfold over the study period. OSA was associated with increased overall postoperative complications, LOS, and readmission, but not with in-hospital mortality. Despite the publication of guidelines favoring RA over GA, the use of GA increased over the study period.

1. Introduction

Obstructive sleep apnea (OSA) is characterized by repetitive upper airway obstruction during sleep, inducing frequent episodes of hypoxemia [1]. The prevalence of OSA is estimated to be between 9% and 38% [2], and is higher in men, older adults, and those with an elevated body mass index [2]. The perioperative management of OSA remains a challenge [3,4], and its coexistence in surgical patients is

Abbreviations: OSA, Obstructive Sleep Apnea; ASA, American Society of Anesthesiologists; THA, total hip arthroplasty; RA, regional anesthesia; GA, general anesthesia; SID, State Inpatient Databases; LOS, length of stay; HCUP, Healthcare Cost and Utilization Project; POA, present-on-admission.

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associated with postoperative hypoxemia, pulmonary and cardiac complications, intensive care unit transfer, longer hospital stay, increased readmission rates, and greater resource utilization [5–9]. In 2006, the American Society of Anesthesiologists (ASA) published clinical practice guidelines for the perioperative management of patients with OSA, which were subsequently updated in 2014 [10,11]. These guidelines recommend perioperative use of positive airway pressure therapy, continuous surveillance, oxygen therapy, and increased utilization of regional anesthesia (RA) (with reciprocal reduction in the use of general anesthesia [GA]) as measures of precaution [10,11].

Total hip arthroplasty (THA) is a common surgical procedure for the treatment of end-stage osteoarthritis that frequently affects older and obese patients [12]. THA can be performed using either RA or GA. Although multiple reports showed evidence of decreased post-operative complications and length of stay (LOS) with the use of RA, there is no clear evidence of superiority of one technique over the other with respect to mortality [13–20]. The prevalence of OSA is higher in patients undergoing orthopedic compared to general surgical procedures [21], and several studies have demonstrated the adverse impact of OSA on morbidity and mortality in orthopedic populations [21,22].

In this study, we sought to investigate the relationship between comorbid OSA and postoperative outcomes in patients undergoing elective THA. We retrospectively analyzed data from the State Inpatient Databases (SID) for Florida, New York, Maryland, and Kentucky for the years 2007–2014. Our main hypothesis was that OSA would increase the unadjusted rate and the adjusted odds of adverse perioperative outcomes after correction for potential confounders in a multivariate logistic regression analysis. The primary outcome was in-hospital mortality, and the secondary outcomes were postoperative complications, LOS, and 30- and 90-day readmission.

A further aim was to explore shifts in practice and outcomes that might represent a response to the initial 2006 publication of the ASA OSA guidelines. Here, we hypothesized: (1) adverse postoperative outcomes associated with OSA would decrease over the study period; (2) the use of RA would increase over the study period; and (3) adverse postoperative outcomes would be lower in patients who received RA as compared to GA.

2. Methods

2.1. Study database and population

This was a retrospective study using administrative billing data associated with inpatient hospitalization and discharge records for all adults (age ≥ 18 years) who underwent elective THA between 2007 and 2014 in the states of Florida, New York, Maryland, and Kentucky. The dataset is taken from the State Inpatient Database (SID), Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality [23]. The SID captures approximately 97% of all U.S. hospital discharges, and includes all patients regardless of insurance status. Each inpatient hospital admission is coded as one individual record; therefore, patients who had multiple eligible surgeries on separate admissions during the study period could conceivably be included in the analysis more than once. HCUP includes present-on-admission (POA) tags for each diagnosis, which are used to differentiate preexisting medical comorbidities from perioperative complications. Validity and internal consistency of the SID data are verified by quality control measures established by HCUP [23].

Inclusion criteria for the study cohort included all adult patients (≥ 18 years) who underwent elective THA defined by the *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) procedure code 81.51. Exclusion criteria were missing demographic or outcome data, and absence or insufficient follow-up time (at least 90 days follow-up). All study activities were approved by the Weill Cornell Medicine Institutional Review Board and subject to a HCUP Data Use Agreement (DUA). Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines were followed [24].

2.1.1. Primary variable of interest

Patients were categorized by the presence/absence of OSA diagnosis (a priori defined as the predictive variable of interest), defined by the presence of ICD-9-CM code 327.23 [20].

2.2. Outcomes

The primary outcome was in-hospital mortality, defined as mortality occurring prior to hospital discharge. Secondary outcomes were postoperative complications, logged length of stay (LOS), and 30- and 90-day readmission. Analyses of readmission were conducted using a HCUP measure (VisitLink) that enables records from one patient to be linked to other inpatient admissions. Non-inpatient admissions, such as emergency room visits, were not considered readmissions.

Postoperative complications were grouped as follows: cardiovascular, pulmonary, gastrointestinal, infectious, and intraoperative; all complications were indicated by the absence of the POA flag in the database [25]. ICD-9-CM codes used for post-operative complications are listed in Supplemental Table 1. Postoperative complications were analyzed individually by group, as well as a composite measure of all complications. To assess for temporal trends, the analysis was performed for the overall study period (2007–2014) and for each individual year.

Additional secondary outcomes were anesthesia type for THA in the OSA population: RA/GA, overall and stratified by year. Analyses related to anesthesia type were restricted to patients in the New York database, as it is the only state in the cohort that reports this information. In these analyses, we included patients with only a single the THA procedure on their record, so that the anesthesia type on the record would be for the THA procedure [16,26]. New York SID contains only one value for anesthesia type, reported hierarchically as general > regional > local > other > no anesthesia. Patients with more than one form of anesthesia administered during the same hospital stay are coded in the following the same hierarchical order; consequently, patients receiving GA and RA will be coded GA. The coding of anesthesia type in the New York SID has been validated [16,26]. In the present study, THA patients were cohorted into two groups according to the type of anesthesia received: RA or GA. Patients coded as receiving local, other, or no anesthesia were excluded from the analysis, as were patients with more than one surgery requiring anesthesia within the same hospital stay [16,26].

2.3. Statistical analysis

Patient demographics, comorbidities, and hospital characteristics were compared based on the presence/absence of OSA across both the full population and the New York-only population. For the New York-only cohort, patients were additionally compared by anesthesia type (RA or GA). Categorical variables were compared using chi-square tests; continuous variables were compared using analysis of variance (ANOVA). Non-parametric equivalents were used when required.

To examine the effect of OSA on postoperative outcomes, we fit multivariable models adjusting for demographic factors, comorbidities, hospital characteristics, and other potential confounders [27]. Dichotomous outcomes were modeled using multivariable mixed effects logistic regression models, clustered on hospital. For continuous outcomes, multivariable general linear models were used. We modeled each outcome separately: in-hospital mortality, any complication (a dichotomous composite measure of cardiovascular, pulmonary, infectious, and intraoperative complications), individual categories of complications, logged LOS, 30-day readmission, and 90-day readmission.

Multivariable models included the following covariates: (i) primary insurance payer (unordered: Medicare, Medicaid, private insurance, uninsured, and other types of insurance); (ii) race/ethnicity (unordered: white, black, Hispanic, other); (iii) state quartile of median income for the patient's ZIP code of residence; (iv) sex; (v) age; (vi) individual

Table 1
Demographic and medical characteristics of patients undergoing THA according to OSA status.

Characteristic	No OSA (%)	OSA (%)	Overall (%)	*P*-value
Total	330,945 (94.8)	18,063 (5.2)	349,008 (100)	
Patient demographics				
Age in years				<.0001
Mean (standard deviation)	65.36 (12.19)	63.27 (10.40)	65.25 (12.11)	
Gender				<.0001
Male	143,382 (43.3)	11,401 (63.1)	154,783 (44.3)	
Female	187,563 (56.7)	6662 (36.9)	194,225 (55.7)	
Race				<.0001
White	274,140 (82.8)	14,974 (82.9)	289,114 (82.8)	
Black	26,168 (7.9)	1560 (8.6)	27,728 (7.9)	
Hispanic	12,709 (3.8)	631 (3.5)	13,340 (3.8)	
Other	12,275 (3.7)	692 (3.8)	12,967 (3.7)	
Missing	5653 (1.7)	206 (1.1)	5859 (1.7)	
Payer				<.0001
Medicare	181,208 (54,8)	9004 (49.8)	190,212 (54.5)	
Medicaid	12,993 (3.9)	550 (3)	13,543 (3.9)	
Private insurance	125,386 (37.9)	7852 (43.5)	133,238 (38.2)	
Other	8342 (2.5)	545 (3)	8887 (2.5)	
Self-pay / No charge	3016 (0.9)	112 (0.6)	3128 (0.9)	
Year				<.0001
2007	34,706 (10.5)	614 (3.4)	35,320 (10.1)	
2008	35,246 (10.7)	1174 (6.5)	36,420 (10.4)	
2009	38,363 (11.6)	1670 (9.2)	40,033 (11.5)	
2010	40,083 (12.1)	2130 (11.8)	42,213 (12.1)	
2011	41,533 (12.5)	2432 (13.5)	43,965 (12.6)	
2012	43,782 (13.2)	2907 (16.1)	46,689 (13.4)	
2013	46,848 (14.2)	3287 (18.2)	50,135 (14.4)	
2014	50,384 (15.2)	3849 (21.3)	54,233 (15.5)	
State				<.0001
Florida	130,012 (39.3)	6174 (34.2)	136,186 (39)	
Kentucky	28,474 (8.6)	2228 (12.3)	30,702 (8.8)	
Maryland	37,046 (11.2)	2476 (13.7)	39,522 (11.3)	
New York	135,413 (40.9)	7185 (39.8)	142,598 (40.9)	
Median household income state quartile for patient zip code - by quartile				<.0001
First quartile	60,090 (18.2)	3145 (17.4)	63,235 (18.1)	
Second quartile	80,232 (24.2)	4212 (23.3)	84,444 (24.2)	
Third quartile	87,038 (26.3)	4893 (27.1)	91,931 (26.3)	
Fourth quartile	96,747 (29.2)	5464 (30.2)	102,211 (29.2)	
Missing	6838 (2.1)	349 (1.9)	7187 (2.1)	
Elixhauser Comorbidities				
Congestive heart failure	5705 (1.7)	798 (4.4)	6503 (1.9)	<.0001
Valvular disease	14,132 (4.3)	842 (4.7)	14,974 (4.3)	0.0115
Pulmonary circulation disorders	2112 (0.6)	350 (1.9)	2462 (0.7)	<.0001
Peripheral vascular disorders	7676 (2.3)	646 (3.6)	8322 (2.4)	<.0001
Hypertension, uncomplicated	180,248 (54.5)	12,101 (67)	192,349 (55.1)	<.0001
Hypertension, complicated	12,923 (3.9)	1311 (7.3)	14,234 (4.1)	<.0001
Paralysis	481 (0.1)	29 (0.2)	510 (0.1)	0.6023
Other neurological disorders	6519 (2)	405 (2.2)	6924 (2)	0.0106
Chronic pulmonary disease	44,752 (13.5)	4557 (25.2)	49,309 (14.1)	<.0001
CPAP use	559 (0.2)	1349 (7.4)	1908 (0.5)	<.0001
Diabetes, uncomplicated	41,825 (12.6)	4475 (24.8)	46,300 (13.3)	<.0001
Diabetes, complicated	2733 (0.8)	425 (2.4)	3158 (0.9)	<.0001
Hypothyroidism	44,055 (13.3)	2632 (14.6)	46,687 (13.4)	<.0001
Renal failure	12,449 (3.8)	1266 (7)	13,715 (3.9)	<.0001
Liver disease	3341 (1)	262 (1.5)	3603 (1)	<.0001
Peptic ulcer disease excluding bleeding	68 (0)	<11 (0.1)	<79 (0)	0.3812
AIDS/HIV	709 (0.2)	20 (0.1)	729 (0.2)	0.003
Lymphoma	1239 (0.4)	68 (0.4)	1307 (0.4)	0.9645
Metastatic cancer	795 (0.2)	27 (0.1)	822 (0.2)	0.0143
Solid tumor without metastasis	1990 (0.6)	108 (0.6)	2098 (0.6)	0.9541
Rheumatoid arthritis/ collagen vascular diseases	13,991 (4.2)	776 (4.3)	14,767 (4.2)	0.6561
Coagulopathy	4349 (1.3)	337 (1.9)	4686 (1.3)	<.0001
Obesity	46,994 (14.2)	8391 (46.5)	55,385 (15.9)	<.0001
Weight loss	788 (0.2)	38 (0.2)	826 (0.2)	0.4551
Fluid and electrolyte disorders	8895 (2.7)	593 (3.3)	9488 (2.7)	<.0001
Blood loss anemia	1213 (0.4)	54 (0.3)	1267 (0.4)	0.1414
Deficiency anemia	21,095 (6.4)	1263 (7)	22,358 (6.4)	0.001
Alcohol abuse	5097 (1.5)	320 (1.8)	5417 (1.6)	0.0143
Drug abuse	2651 (0.8)	196 (1.1)	2847 (0.8)	<.0001
Psychoses	4356 (1.3)	399 (2.2)	4755 (1.4)	<.0001
Depression	34,685 (10.5)	3146 (17.4)	37,831 (10.8)	<.0001

P-values refer to comparisons between OSA statuses. Continuous variables analyzed using analysis of variance; categorical variables analyzed using Pearson chi-square test or Fisher exact test. Mean (standard deviation). Percent may not sum to 100 due to rounding and missing values.
THA: total hip arthroplasty, OSA: obstructive sleep apnea.

Elixhauser comorbidities with a significance level of <0.05 in bivariate analyses by OSA status; (vii) year of surgery; (viii) hospital volume of THA surgeries (in quartiles based on the distribution of volume in our sample); and (ix) in-hospital continuous positive airway pressure (CPAP) use, including invasive (ICD-9-CM 96.7, Other continuous invasive mechanical ventilation, which includes "CPAP delivered through endotracheal tube or tracheostomy") and non-invasive (ICD-9-CM 93.90, Non-invasive mechanical ventilation). In models of 30- and 90-day readmission logged values of LOS were also included as covariates (to account for initial hospitalization). We additionally stratified our analyses by sex. The list of individual Elixhauser comorbidities included in the analyses is reported in Table 1.

For each outcome, an additional model with an interaction term for the categorical year variable and OSA status was included. These models were compared with the corresponding main model using a likelihood ratio test. If the likelihood ratio test indicated that the model with the interaction term was superior to the main model, we calculated a linear combination of coefficients for significant interaction terms. Additional models for each outcome were fit for each year.

We fit additional multivariable models for an exploratory analysis of New York data, in which we examined the effect of OSA on the

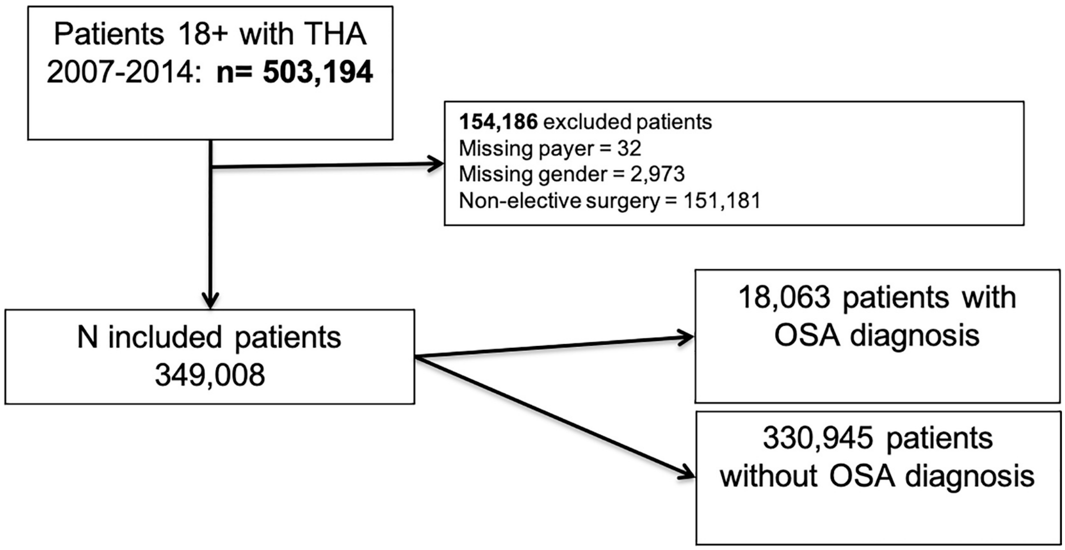

Fig. 1. Flowchart of the overall study population.
THA: total hip arthroplasty, OSA: obstructive sleep apnea.

Table 2
Frequency and risk-adjusted odds of outcome measures for patients undergoing THA according to OSA status.

Outcome	No. (%)	OR (95% CI)
In-hospital mortality		
No OSA	313 (0.1)	1.00 (reference)
OSA	14 (0.1)	0.57 [0.31,1.04]
Any complication		
No OSA	15,687 (4.7)	1.00 (reference)
OSA	2603 (14.4)	1.53*** [1.44,1.63]
Cardiovascular complication		
No OSA	4139 (1.3)	1.00 (reference)
OSA	330 (1.8)	1.24*** [1.09,1.41]
Pulmonary complication		
No OSA	6212 (1.9)	1.00 (reference)
OSA	2002 (11.1)	1.98*** [1.81,2.17]
Infectious complication		
No OSA	4406 (1.3)	1.00 (reference)
OSA	294 (1.6)	1.08 [0.95,1.23]
Intraoperative complication		
No OSA	1263 (0.4)	1.00 (reference)
OSA	68 (0.4)	0.96 [0.73,1.25]
Gastrointestinal complication		
No OSA	1622 (0.5)	1.00 (reference)
OSA	162 (0.9)	1.36*** [1.13,1.62]
LOS (days, logged)		
No OSA	3 (3, 4)^	1.00 (reference)
OSA	3 (3, 4)^	1.03*** [1.03,1.04]
30-day readmission		
No OSA	12,676 (4.8)	1.00 (reference)
OSA	866 (6.4)	1.16*** [1.07,1.25]
90-day readmission		
No OSA	24,205 (9.2)	1.00 (reference)
OSA	1571 (11.7)	1.09** [1.03,1.16]

Percent may not sum to 100 due to rounding and missing values. $^{**}p < 0.01$; $^{***}p < 0.001$; ^ Median (IQR).
THA: total hip arthroplasty, OSA: obstructive sleep apnea.

likelihood of receiving RA versus GA for THA.

Data is presented as N (percentage), mean (standard deviation), median (interquartile range), adjusted odds ratio (aOR, 95% confidence interval), or difference in expected geometric means. Bivariate analyses were conducted in SAS version 9.4 (Cary, NC, USA), and multivariate analyses were conducted in Stata SE version 16.1 (College Station, TX, USA).

3. Results

After exclusion of patients with missing data and non-elective surgery ($n = 154{,}186$), the study population consisted of 349,008 unique patients (mean age 65 ± 12 years, male/female 44.3%/55.7%) (Fig. 1). Within this cohort, 18,063 patients (5.2%) presented with the POA diagnosis of OSA. The prevalence of OSA in our sample population increased temporally from 1.7% in 2007 to 7.1% in 2014.

Patient demographic characteristics are presented in Table 1. Compared to patients without an OSA diagnosis, patients with OSA were younger (63.27 ± 10.4 years vs. 65.4 ± 12.2 years for OSA and non-OSA patients, respectively), more likely to be male (63.1% vs. 43.3%, respectively), obese (46.5% vs. 14.2%), and present with a higher prevalence of most individual comorbidities, including hypertension, diabetes, chronic pulmonary disease, use of CPAP, renal failure and liver disease, coagulopathy, psychiatric and addictive disorders.

3.1. Primary and secondary outcomes

When comparing postoperative outcomes between OSA and non-OSA populations (Table 2 and Fig. 3), we found no difference in in-hospital mortality between the two groups (0.1% for OSA and non-OSA patients, respectively; aOR 0.57 [0.31–1.04]). OSA diagnosis was associated to a higher rate overall (14.4% vs 4.7%, aOR 1.53 [1.44, 1.63], cardiovascular (1.8% vs. 1.3%, aOR 1.24 [1.09, 1.41]), pulmonary (11.1% vs. 1.9%, aOR 1.98 [1.81, 2.17]) and gastrointestinal (0.9% vs. 0.5%, aOR 1.36 [1.13, 1.62]) complications. OSA was associated with a longer LOS compared with patients without OSA. Additionally, the rates of 30-day (6.4% vs.4.8%, aOR 1.16 [1.07, 1.25]) and 90-day (11.7% vs. 9.2%, aOR 1.09 [1.03, 1.16]) readmission were significantly higher in patients with OSA. No difference between OSA and non-OSA populations was found in the infectious and intraoperative complication rates. After sex stratification, OSA was associated with the same post-operative outcomes with the addition of infectious complication in men.

In the OSA population, with 2007 taken as the reference year, we found no temporal trend in in-hospital mortality, complication rate and LOS over the study period (Table 3). Compared to 2007, the odds of 30-day readmission in the OSA population were significantly lower in 2013 (aOR 0.67 and 0.63 [0.47–0.95]), and 2014 (aOR 0.63 [0.45–0.90]) while it was significantly lower for 90-day readmission from the 2009 and all the subsequent years (aOR range: 0.71–0.93), including after sex

Table 3
Risk-adjusted odds of outcome measures for OSA patients undergoing THA according to the year of the surgery.

	In-hospital mortality	Any complication	LOS (logged)	30-day readmission	90-day readmission
2007 (Reference)	1.00	1.00	1.00	1.00	1.00
	[1.00,1.00]	[1.00,1.00]	[1.00,1.00]	[1.00,1.00]	[1.00,1.00]
2008	1.39	1.06	1.14	1.20	0.97
	[0.11,17.25]	[0.70,1.62]	[0.80,1.61]	[0.83,1.75]	[0.93,1.01]
2009	1.00	0.99	1.23	1.09	0.93***
	[1.00,1.00]	[0.66,1.48]	[0.89,1.70]	[0.76,1.57]	[0.89,0.96]
2010	1.00	0.77	1.00	1.05	0.90***
	[1.00,1.00]	[0.52,1.15]	[0.72,1.38]	[0.74,1.50]	[0.87,0.93]
2011	4.96	1.05	1.24	0.95	0.87***
	[0.94,26.17]	[0.71,1.54]	[0.90,1.69]	[0.67,1.36]	[0.84,0.90]
2012	1.81	0.87	0.99	0.74	0.81***
	[0.28,11.61]	[0.59,1.27]	[0.73,1.35]	[0.52,1.06]	[0.79,0.84]
2013	0.54	0.81	1.09	0.67*	0.77***
	[0.05,6.30]	[0.55,1.18]	[0.80,1.48]	[0.47,0.95]	[0.74,0.80]
2014	1.00	0.70	1.00	0.63*	0.71***
	[1.00,1.00]	[0.48,1.04]	[0.73,1.37]	[0.45,0.90]	[0.68,0.73]

Exponentiated coefficients; 95% confidence intervals in brackets.
THA: total hip arthroplasty, OSA: obstructive sleep apnea, LOS: length of stay.
* $p < 0.05$.
*** $p < 0.001$.

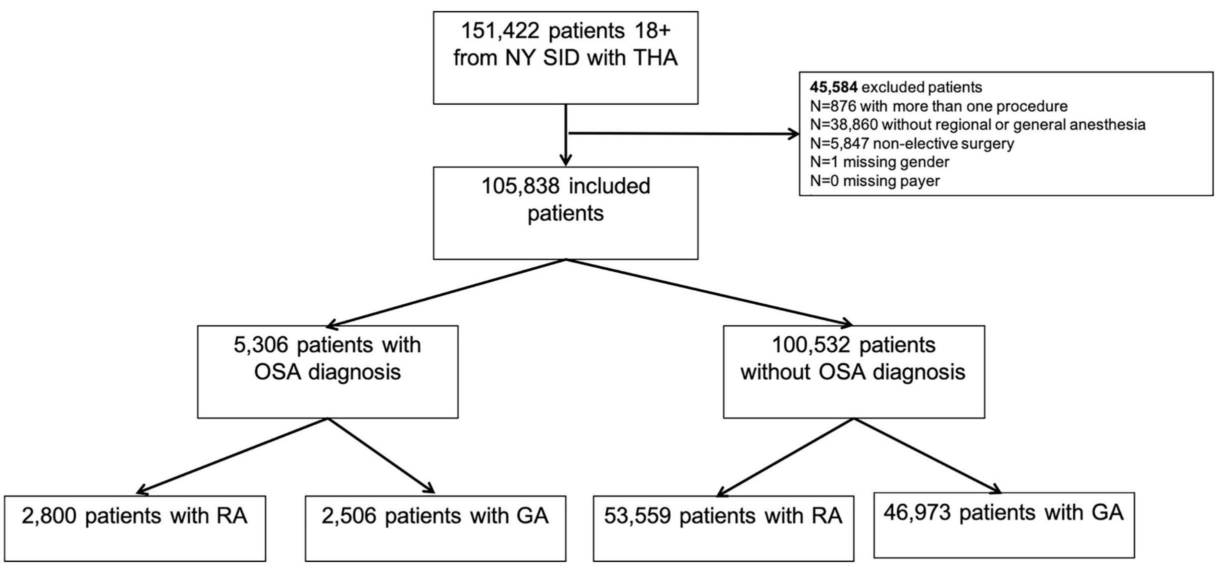

Fig. 2. Flowchart of the New York SID study population.
THA: total hip arthroplasty, OSA: obstructive sleep apnea, NY SID: New York State Inpatient Databases, RA: regional anesthesia, GA: general anesthesia.

stratification.

3.2. Anesthetic type analysis

After exclusions ($n = 45{,}584$), the sub-group population of patients from the New York SID consisted of 105,838 unique patients (mean age 65 ± 12 years, male/female 44.3%/55.7%), including 5306 patients (5%) with the diagnosis of OSA (Fig. 2). 53.3% ($n = 53{,}559$) received RA in the overall population, while 52.8% ($n = 2800$) received RA in the OSA population.

There was no difference in the mortality rate between anesthesia types (0.2% vs. 0.1% for GA and RA, respectively, aOR 1.00 [1.00, 1.00]) (Table 4). Additionally, we found no differences in complication rates, readmission and LOS in patients with GA compared to those with RA. After sex stratification, we found higher odds of pulmonary (aOR 2.09 [1.09–4.01]) and any complications (aOR 1.57 [1.02–2.41]) in men receiving GA and higher adjusted odds of 90-day readmission (aOR 1.44 [1.00–2.06]) in women receiving GA (Table 4). For patients with OSA, the odds of receiving GA generally increased over the study period (Table 5), including after sex stratification.

4. Discussion

We retrospectively analyzed the effect of OSA on postoperative outcomes in a large cohort of patients undergoing THA over an 8-year time period (2007–2014). In the main analysis, after adjustment for co-morbidities, we identified no difference in our primary outcome which was in-hospital mortality. However, secondary outcomes analysis evidenced that OSA was associated with higher complication rates, longer LOS, and higher 30- and 90-day readmission rates. These results are consistent with previous reports from both the orthopedic and general surgery populations [14,19,20,22,28].

We identified an increase in the reported prevalence of OSA over the years, from 1.7% in 2007 to up to 7.1% in 2014. This increase has a number of potential explanations, including increases in the rate of obesity [29,30] and aging [31] in the general population. It may also result from increased OSA screening, or from increased administrative reporting of OSA. It is important to note that any under-coding of OSA

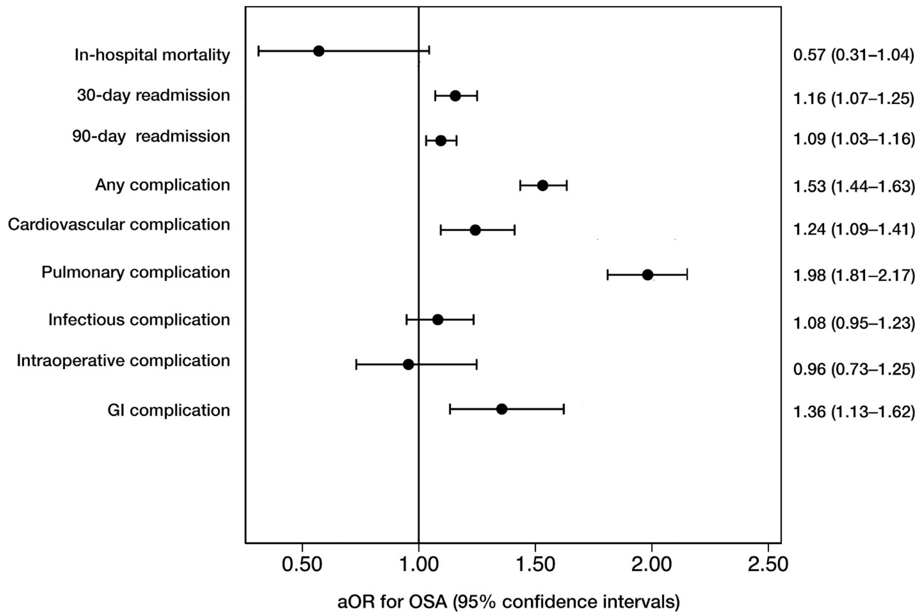

Fig. 3. Forest plot for the risk-adjusted odds of outcome measures for patients undergoing THA according to OSA status.

Table 4
Frequency and risk-adjusted odds of outcome measures for patients undergoing THA in the New York State Inpatient Databases population with OSA diagnosis, according to the anesthesia type for the overall population and stratified by sex.

	Overall		Male		Female	
Outcome			No. (%)	OR (95% CI)	No. (%)	OR (95% CI)
In-hospital mortality						
RA	0 (<0.0)	1.00 (reference)	0 (<0.0)	1.00 (reference)	0 (<0.0)	1.00 (reference)
GA	<11 (<0.2)	1.00 (1.00,1.00)	<11 (<0.7)	^^	<11 (<0.1)	^^
Any complication						
RA	543 (19.4)	1.00 (reference)	353 (18.6)	1.00 (reference)	190 (21.1)	1.00 (reference)
GA	379 (15.1)	1.23 (0.87,1.73)	259 (16.5)	1.57* (1.02,2.41)	120 (12.8)	0.87 (0.52,1.48)
Cardiovascular complication						
RA	33 (1.2)	1.00 (reference)	21 (1.1)	1.00 (reference)	12 (1.3)	1.00 (reference)
GA	41 (1.6)	1.13 (0.65,1.98)	28 (13.9)	1.24 (0.61,2.51)	13 (1.4)	1.21 (0.42,3.43)
Pulmonary complication						
RA	489 (17.5)	1.00 (reference)	321 (16.9)	1.00 (reference)	168 (18.7)	1.00 (reference)
GA	319 (12.7)	1.46 (0.91,2.34)	217 (13.9)	2.09* (1.09,4.01)	102 (10.9)	1.14 (0.58,2.26)
Infectious complication						
RA	25 (0.9)	1.00 (reference)	<11 (<0.6)	1.00 (reference)	18 (2.0)	1.00 (reference)
GA	18 (0.7)	0.76 (0.34,1.74)	<11 (<0.7)	1.86 (0.57,6.05)	<11 (<1.2)	0.30* (0.11,0.86)
Intraoperative complication						
RA	<11 (<0.4)	1.00 (reference)	<11 (<0.6)	1.00 (reference)	<11 (<1.2)	1.00 (reference)
GA	<11 (0.4)	0.05 (0.00,1.37)	<11 (<0.7)	^^	<11 (<1.2)	^^
Gastrointestinal complication						
RA	13 (0.5)	1.00 (reference)	11 (0.6)	1.00 (reference)	<11 (<1.2)	1.00 (reference)
GA	26 (1)	1.56 (0.71,3.41)	21 (1.3)	^^	<11 (<1.2)	^^
LOS (days, logged)						
RA	3 (3, 4)^	1.00 (reference)	3 (3, 4)^	1.00 (reference)	3 (3, 4)^	1.00 (reference)
GA	3 (3, 4)^	0.98 (0.96,1.00)	3 (3, 4)^	1.02 (0.99,1.04)	3 (3, 4)^	0.92*** (0.89,0.95)
30-day readmission						
RA	127 (4.7)	1.00 (reference)	81 (4.5)	1.00 (reference)	46 (5.3)	1.00 (reference)
GA	141 (5.9)	1.10 (0.81,1.50)	84 (5.6)	1.05 (0.71,1.54)	57 (6.3)	1.43 (0.90,2.28)
90-day readmission						
RA	217 (8.1)	1.00 (reference)	138 (7.6)	1.00 (reference)	79 (9.1)	1.00 (reference)
GA	240 (10)	1.22 (0.94,1.58)	142 (9.5)	1.25 (0.95,1.65)	98 (10.9)	1.44* (1.00,2.06)

Percent may not sum to 100 due to rounding and missing values. ** $p < 0.01$; *** $p < 0.001$; ^ Median (IQR).
^^ Model unable to be fit due to non-convergence.
THA: total hip arthroplasty, OSA: obstructive sleep apnea, RA: regional anesthesia, GA: general anesthesia.

should be at random and would tend to favor the null hypothesis, and should not be seen to diminish the study's positive findings.

According to the temporal trends over the study period, we found that within the OSA population, rate of readmission temporally decreased. This difference is unlikely to be specific to the OSA population, but instead may represent a general trend in all populations and orthopedic surgery types, attributable at least in part to enhanced recovery short-stay programs that have shown reductions in readmission rate [32–34].

In the sub-group of patients from New York, for whom comparison of anesthesia type was possible, we found no association between anesthesia type and post-operative outcomes. Surprisingly, in contradiction

Table 5
Proportion and risk-adjusted odds of use of general anesthesia (compared to regional anesthesia) for THA in OSA patients in the New York State Inpatient Databases population according to the year of the surgery.

Year	No. (%)	OR (95% CI)
2007	86 (39.8)	1.00 (reference)
2008	133 (43)	1.08 (0.73,1.60)
2009	224 (46.1)	1.38 (0.96,1.98)
2010	307 (46.9)	1.48* (1.04,2.10)
2011	347 (49.6)	1.48* (1.05,2.10)
2012	427 (51.9)	1.82*** (1.29,2.56)
2013	421 (47.7)	1.60** (1.14,2.26)
2014	561 (45.3)	1.25 (0.90,1.75)

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

to our hypothesis that the use of GA would decrease following publication of guidelines, we found an increased use of GA in the OSA population over the study period.

Comparatively, Memtsoudis et al. performed a comparison in a cohort of 30,024 unique patients with hip or knee arthroplasty using large administrative databases within the United States between 2006 and 2010. They found that 74% of patients received GA, 15% received combined anesthesia, and only 11% received RA exclusively [13]. Neuman et al. conducted a comparative study using a cohort of 56,729 patients with hip fracture included in New York State databases between 2004 and 2011, and found that 28% received RA [16]. Our study found a higher proportion of patients receiving RA (53.3%). These differences likely reflect the high variability of practice according to each individual institution's preferences as well as the level of emergency, as previously suggested [35].

Memtsoudis et al. showed that GA was associated with higher rates of pulmonary, gastrointestinal and infectious complications compared to RA. In contrast, Pichler et al., found no correlation between the anesthetic technique and the rate of complications [20]. However, in that study more than 90% of patients received RA, indicating that the cohort may not be generalizable to a broad population. Naqvi et al. performed a study in 1246 patients with OSA and receiving total joint arthroplasty between 2006 and 2016, matching the cohort in a 1:3 ratio with controls and evaluating postoperative complications between according to anesthesia type [14]. The authors found an association between GA and pulmonary, cardiac, gastrointestinal, and wound complications. They also found a higher mortality in GA compared to RA, reinforcing the potential benefits of using RA in orthopedic patients. Our results add further evidence in favor of RA as we identified higher rates of complications, mainly pulmonary complications, in male patients with OSA that received GA and higher 90-day readmission in female patients with OSA when compared to those receiving RA. These results reinforce the ASA guideline recommendations, and emphasize the importance of using RA whenever possible in the OSA population [10,11]. However, our analysis of the temporal trend in the use of GA in the OSA population over the study period showed an increase in GA use from 2007 to 2014. According to administrative data recording, our results cannot discriminate if this increase reflects an increase use of GA alone or in combination with RA. Nevertheless, these results highlight a lack of clinical application of ASA guidelines, and are consistent with previously published data showing a drop in RA utilization in orthopedic surgery [36,37]. One explanation might be a paucity of highest-level prospective evidence supporting the benefit of RA on postoperative outcomes, particularly critical outcomes such as mortality or cardiac complications [38]. Nevertheless, different anesthesia expert groups strongly recommend the use of RA in both the OSA population and in orthopedic surgery [10,11,39]. It is hoped that large randomized controlled trials, and notably the REGAIN trial in 1600 patients with hip fracture, will provide more definitive evidence [40].

The present study has limitations. The retrospective design of our study only allowed us to show correlation and not causation. Data extracted from the HCUP-SID administrative database limited the qualitative analysis of covariates and may lack clinical relevance. The administrative coding of an OSA diagnosis requires accurate coding in the medical record and then accurate translation into an administrative code. There is then a risk of under-diagnosis in the study population, as illustrated by the lower rate of OSA diagnosis in the study cohort (4.9%) compared to the general population (8–38%) [2,41,42]. However, as mentioned previously, we believe that undercounting the OSA diagnosis will favor the null hypothesis and would bias against the findings of the study (our alternative hypothesis). The administrative coding of the database is also the reasons for other limitations of the present study: (1) Patients receiving both GA and RA during the same clinical intervention are coded as GA, which could bias understandably bias analysis and limit calculated differences between anesthesia type cohorts. We believe that this misattribution coding would serve to bias towards the null and against the alternative hypothesis. As a consequence, the present results reflect the use of GA, used alone or in combination with any RA technique and the use of RA, used without GA. (2) Additionally, the type of RA (e.g. neuraxial technique vs peripheral nerve block) was not available and thus could not be investigated. (3) The SID is unable to identify readmissions of patients readmitted to hospitals in different states than the index procedure state. (4) The SID database does not have information on BMI other than prevalence of obesity. Because BMI was not recorded numerically, the severity of obesity over time could not be studied. Additionally, it should be noted that this study did not specifically test for or adjust for the worsening of obesity over time that might prohibit adoption and application of RA in OSA orthopedic populations [43]. The rationale of including data from 2007 to 2014 was to investigate the influence of ASA guidelines publication that was first published in 2006. More recent data would be meaningful to analyze. However, at the time of this analysis, we did not have data beyond 2014.

In summary, in a large population-based cohort, we found an increase in the prevalence of OSA in patients undergoing THA, and found that OSA was associated with an increased frequency of several important negative postoperative outcomes. We found higher rates of complication and 90-days readmission with the use of GA as compared to RA, providing support for the recommended use of RA in patients with OSA published in ASA guidelines since 2006. However, despite these recommendations, we found evidence that the use of GA in the OSA population paradoxically increased over the study period. More effort is required to implement ASA guidelines in clinical practice, and our results confirm the advantage of RA in the OSA population.

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Declaration of Competing Interest

The authors have nothing to disclose.

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NA.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclinane.2020.110159.

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