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Risks Associated With Anesthesia Services During Colonoscopy

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CLINICAL AT

This article has an accompanying continuing medical education activity on page e18. Learning Objective: Upon completion of this test, successful learners will be able to (1) list colonoscopy complications associated with anesthesia instead of IV conscious sedation; (2) describe geographic diversity in use of anesthesia services in performance of colonoscopy; (3) describe polypectomy complications associated with use of anesthesia for colonoscopy.

See editorial on page 801.

BACKGROUND & AIMS: We aimed to quantify the difference in complications from colonoscopy with vs without anesthesia services. **METHODS:** We conducted a prospective cohort study and analyzed administrative claims data from Truven Health Analytics MarketScan Research Databases from 2008 through 2011. We identified 3,168,228 colonoscopy procedures in men and women, aged 40–64 years old. Colonoscopy complications were measured within 30 days, including colonic (ie, perforation, hemorrhage, abdominal pain), anesthesia-associated (ie, pneumonia, infection, complications secondary to anesthesia), and cardiopulmonary outcomes (ie, hypotension, myocardial infarction, stroke), adjusted for age, sex, polypectomy status, Charlson comorbidity score, region, and calendar year. **RESULTS:** Nationwide, 34.4% of colonoscopies were conducted with anesthesia services. Rates of use varied significantly by region (53% in the Northeast vs 8% in the West; $P < .0001$). Use of anesthesia service was associated with a 13% increase in the risk of any complication within 30 days (95% confidence interval [CI], 1.12–1.14), and was associated specifically with an increased risk of perforation (odds ratio [OR], 1.07; 95% CI, 1.00–1.15), hemorrhage (OR, 1.28; 95% CI, 1.27–1.30), abdominal pain (OR, 1.07; 95% CI, 1.05–1.08), complications secondary to anesthesia (OR, 1.15; 95% CI, 1.05–1.28), and stroke (OR, 1.04; 95% CI, 1.00–1.08). For most outcomes, there were no differences in risk with anesthesia services by polypectomy status. However, the risk of perforation associated with anesthesia services was increased only in patients with a polypectomy (OR, 1.26; 95% CI, 1.09–1.52). In the Northeast, use of anesthesia services was associated with a 12% increase in risk of any complication; among colonoscopies performed in the West, use of anesthesia services was associated with a 60% increase in risk. **CONCLUSIONS:** The overall risk of complications after colonoscopy increases when individuals receive anesthesia services. The widespread adoption of anesthesia services with colonoscopy should be considered within the context of all potential risks.

Keywords: Anesthesia Services; Endoscopy; Propofol; Gastroenterology.

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Colonoscopy is the most common colorectal cancer screening test in the United States among average-risk adults.[1] Nearly all colonoscopies conducted in the United States are performed with medication to reduce discomfort and improve the performance of the test, usually a combination of benzodiazepine and a narcotic (ie, standard sedation) to provide moderate sedation.[2] In the past 10 years, the use of propofol for endoscopy sedation has increased.[3] Propofol is preferred in some settings because sedation occurs rapidly and patients experience a shorter recovery time than standard sedation. The involvement of anesthesia services for colonoscopy sedation, mainly to administer propofol, has increased accordingly, from 11.0% of colonoscopies in 2001 to 23.4% in 2006,[4] with projections of more than 50% in 2015.[5]

Whether the use of propofol is associated with higher rates of short-term complications compared with standard sedation is not well understood. A recent Cochrane review found no evidence of differences in health outcomes after colonoscopy with administration of propofol compared with standard sedation.[6] However, many of the studies included

Abbreviations used in this paper: CI, confidence interval; CPT, Current Procedural Terminology; ICD-9-CM, International Classification of Diseases, 9th revision, Clinical Modification; OR, odds ratio; SEER, Surveillance, Epidemiology and End Results.

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in the review had relatively small sample sizes that would not have been able to detect rare outcomes, such as colonic perforation or cardiac outcomes. There are plausible reasons as to why deep sedation with anesthesia during a colonoscopy could increase patients' risks of adverse outcomes, such as aspiration when a sedated patient cannot protect their airway, or perforation when patients are not able to provide feedback to the endoscopist regarding excessive pressure.[7] In studies conducted with claims-based data, the ascertainment of propofol is made by the identification of receipt of anesthesia services with a colonoscopy. In a previous study among Surveillance, Epidemiology, and End Results (SEER) Program–Medicare patients undergoing a colonoscopy from 2000 to 2009, Cooper et al[8] determined that overall complications rates, specifically aspiration pneumonia, were more common among colonoscopies with anesthesia services (0.22%) compared with procedures without anesthesia services (0.16%).

The purpose of our analysis was to compare the risks of colonic, anesthesia-associated, and cardiopulmonary complications between colonoscopies performed with anesthesia services compared with colonoscopies performed without anesthesia services among adults aged 40–64 years.

Materials and Methods

Study Design and Population

We conducted an observational cohort study using the Commercial Claims and Encounters Database available from Truven Health Analytics MarketScan Research Databases (Ann Arbor, MI) to identify a cohort of men and women aged 40–64 years who had undergone an outpatient colonoscopy between January 1, 2008, and December 31, 2011. These data included health insurance claims across the continuum of care (eg, inpatient, outpatient, outpatient pharmacy) and insurance enrollment data from employer-based health plans across the United States, which provided coverage for millions of employees, their spouses, and their dependents. This administrative claims database includes a variety of fee-for-service, preferred provider organizations, and capitated health plans. This study was considered exempt from Institutional Review Board review because we accessed de-identified publicly available data in the analysis.

Colonoscopy Identification

Colonoscopy procedures were identified using Current Procedural Terminology (CPT) codes (45378-45386 and 45391-45392), International Classification of Diseases, 9th revision, Clinical Modification (ICD-9-CM) codes (45.23 and 48.36), and Healthcare Common Procedure Coding System codes (G0105 and G0121). We restricted the cohort to patients with at least 1 year of health insurance enrollment before the colonoscopy to enable observation of comorbid conditions. We excluded cohort members with prevalent disease conditions that are associated with an increased risk for colorectal cancer, including Crohn's disease (ICD-9-CM code, 555), ulcerative colitis (ICD-9-CM code, 556), or inflammatory bowel disease (ICD-9-CM code, 558.9), and members with a prior diagnosis of colorectal cancer (ICD-9-CM codes, 153–154) within 1 year of the colonoscopy. When cohort members had more than one colonoscopy during the study period, we selected the first colonoscopy.

Ascertainment of Anesthesia Use

We assumed that colonoscopy was performed with propofol if anesthesia services were billed in conjunction with a colonoscopy conducted on the same day (CPT code, 00810; or Healthcare Common Procedure Coding System, J3490). We assumed that all other colonoscopies were performed with standard sedation in the absence of a billing code for anesthesia services.[8,9]

Patient Covariates

Observed patient covariates included sex and age at time of colonoscopy, and comorbidities based on the Charlson comorbidity index.[10] The Charlson comorbidity index was calculated using inpatient diagnoses recorded during the year before the colonoscopy. For each colonoscopy, we determined whether there was polypectomy (yes/no) based on billing codes indicating tissue removal (biopsy: CPT code, 45380; polypectomy: CPT codes, 45383, 45384, and 45385; and ICD-9-CM codes, 45.43 and 48.36). We also used billing codes to ascertain the provider and practice type (gastroenterology vs other). Other provider and practice types included surgeons, ambulatory centers, and physicians not otherwise specified. We also identified the geographic region where the examination was performed based on a 3-digit zip code (ie, Northeast, Southeast, Midwest, Southwest, West, and unknown).

Outcome Measures

ICD-9-CM codes indicating colonoscopy complications were derived from prior research that collated inpatient and outpatient events associated with verified colonoscopy complications within 30 days after the date of the colonoscopy.[11,12] Our primary outcomes of interest included the following: (1) colonic events: perforation (ICD-9-CM code, 569.83); hemorrhage (ICD-9-CM codes, 578 and 578.1); abdominal pain (ICD-9-CM codes, 789.0–789.09); (2) sedation-associated events: pneumonia (ICD-9-CM codes, 507 and 507.8), infection (ICD-9-CM codes, 780.6, 790.7, 424.9–424.99, and 789.0–789.09), and complications secondary to anesthesia (ICD-9-CM codes, 995.4, 997.1, and 997.3); and (3) cardiopulmonary events: hypotension (ICD-9-CM codes, 458, 458.0, 458.2, 458.8, and 458.9); myocardial infarction (ICD-9-CM codes, 410–410.9); and stroke and other central nervous system events (ICD-9-CM codes, 430, 431, 432, 432.0, 432.1, 432.9, 434.01, 434.9, and 436).

Statistical Analysis

We describe the characteristics of individuals who received a colonoscopy with and without anesthesia services using means and proportions, as appropriate. We used ArcGIS (Esri, Redlands, CA) to produce US maps indicating the prevalence of use of anesthesia services with a colonoscopy comparing 2008–2009 vs 2010–2011.

In our primary analysis, we used multivariable logistic regression to estimate the association between the use of anesthesia services and any adverse outcome, described earlier, within 30 days of the colonoscopy claim. In addition, we estimated separate multivariable logistic regression models for

Table 1. Descriptive Statistics of US Adults Aged 40–64 Years Who Received a Colonoscopy Between 2008 and 2011 by Use of Standard Sedation Compared With Anesthesia Services

	Standard sedation (N = 2,079,784)		Anesthesia services (N = 1,088,444)		
Characteristics	N	%	N	%	Total
Age, *y*					
40–44	118,219	5.7	65,789	6.0	184,008
45–49	202,027	9.7	110,740	10.2	312,767
50–54	718,696	34.6	366,116	33.6	1,084,812
55–59	545,729	26.2	284,265	26.1	829,994
60–64	495,113	23.8	261,534	24.0	756,647
Sex					
Men	972,911	46.8	506,003	46.5	1,478,914
Women	1,106,873	53.2	582,441	53.5	1,689,314
Charlson comorbidity score					
0	2,047,467	98.4	1,071,580	98.4	3,119,048
1	22,164	1.1	11,833	1.19	33,997
≥2	10,153	0.5	5,031	0.5	15,184
Region					
Northeast	219,226	10.5	251,582	23.1	470,808
Southeast	307,652	14.8	229,746	21.1	537,398
Southwest	472,765	22.7	156,243	14.4	629,008
Midwest	271,868	13.1	82,848	7.6	354,716
West	284,855	13.7	24,355	2.2	309,210
Unknown	*523,418*	*25.2*	*343,670*	*31.6*	*867,088*
Year of colonoscopy					
2008	513,019	24.7	212,110	19.5	725,129
2009	627,188	30.2	302,066	27.8	929,254
2010	507,881	24.4	278,567	25.6	786,448
2011	431,696	20.8	295,701	27.2	727,397
Provider type					
Gastroenterology	915,732	44.0	534,847	49.1	1,450,579
Not gastroenterology	1,164,052	56.0	553,597	50.9	1,717,649
Polypectomy					
No	1,108,236	53.3	571,518	52.5	1,679,754
Yes	971,548	46.7	516,926	47.5	1,488,474

each adverse outcome. All models were adjusted for sex, age, polypectomy status, Charlson comorbidity score, provider/practice type, calendar year, and geographic region. Because there could be regional variation in the type of patient receiving anesthesia services in conjunction with colonoscopy, we also report results stratified by region. All results were stratified further by polypectomy status at the time of the colonoscopy (yes/no). Results are presented as odds ratios with 95% confidence intervals.

We conducted one sensitivity analysis that restricted outcomes to inpatient hospitalizations to explore whether outpatient claims (ie, likely less serious outcomes) were driving the relationship between use of anesthesia services and adverse outcomes.

All analyses were conducted using Stata version 12.0 (College Station, TX).[13]

Results

Overview of the Population

We identified 4,939,993 individuals who had colonoscopies during the study period. We excluded 1,491,943 with less than 1 year of enrollment, 39,784 with a previous diagnosis of colorectal cancer, and 240,038 with other noncancer exclusions. Our final sample included 3,168,228 unique colonoscopies.

Study participants were, on average, 54.5 years of age, 53.3% were female, and 45.8% had their colonoscopy performed by a gastroenterologist. There were no differences in the proportion of adults who received anesthesia services vs no anesthesia services by age, sex, Charlson comorbidity score, or receipt of polypectomy (Table 1). Nearly a quarter of colonoscopies conducted with anesthesia services were performed in the Northeast and Southeast compared with less than 3% in the West. Use of anesthesia services was more common in colonoscopies conducted recently (2010–2011) compared with earlier years (2008–2009).

Main Analysis

Nationwide, 34.4% of colonoscopies were conducted with anesthesia services. Rates of use varied significantly with region (53% in the Northeast vs 8% in the West; $P < .0001$) and time. In all regions of the United States, the prevalence of claims for anesthesia services with a

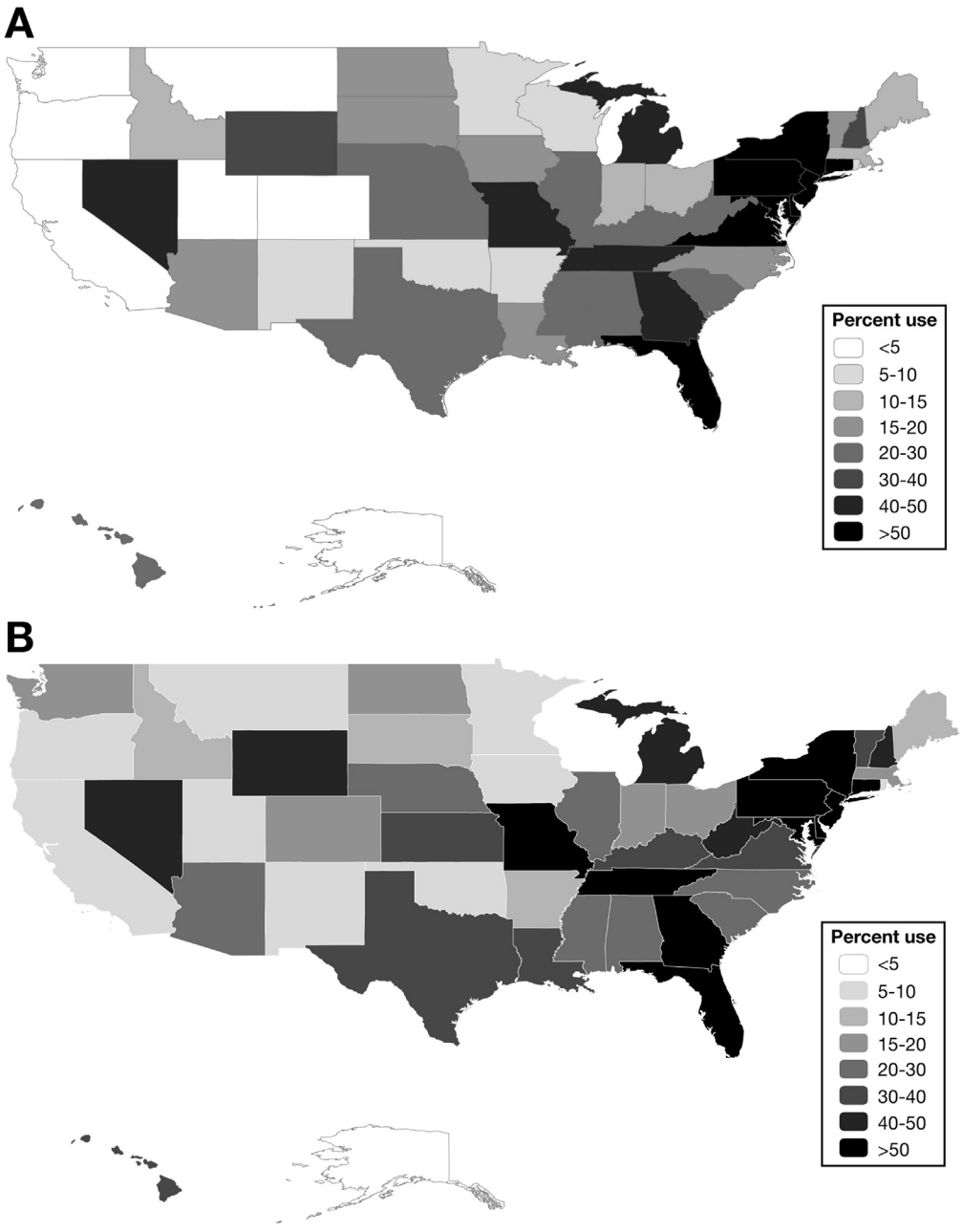

Figure 1. Prevalence of anesthesia services in the 50 US states in (*A*) 2008–2009 and (*B*) 2010–2011.

colonoscopy increased from 2008–2009 to 2010–2011 (Figure 1). The use of anesthesia services was highest in Florida, increasing from 73.5% of colonoscopies in 2008–2009 to 79.3% of colonoscopies in 2010–2011. In contrast, the use of anesthesia services was lowest in Washington, where only 3.7% of colonoscopies were performed with anesthesia services in 2008–2009 to a nearly 5-fold increase to 15.4% of colonoscopies in 2010–2011.

Use of anesthesia services was associated with a 13% higher risk of any complication within 30 days (95% confidence interval [CI], 1.12–1.14) (Table 2). Use of anesthesia services was associated specifically with a higher risk of perforation (odds ratio [OR], 1.07; 95% CI, 1.00–1.15); hemorrhage (OR, 1.28; 95% CI, 1.27–1.30); abdominal pain (OR, 1.07; 95% CI, 1.05–1.08), complications secondary to anesthesia (OR, 1.15; 95% CI, 1.05–1.28), and stroke and other central nervous system events (OR, 1.04; 95% CI, 1.00–1.08) (Table 2). When stratified by polypectomy, the results for any complication and each individual outcome remained similar to the overall results, except for perforation. Among those with a polypectomy, the risk of perforation was 26% higher with receipt of anesthesia services; however, there was no association between anesthesia services and perforation among individuals without polypectomy (OR, 1.04; 95% CI, 0.88–1.24).

Analyses that stratified by region also showed that use of anesthesia services was associated with a higher risk of

Table 2. Risk of 30-Day Outcomes by ORs and 95% CIs of the Association Between Use of Anesthesia Services and Standard Sedation

Outcomes	Overall		Polypectomy		No polypectomy	
	OR[a]	95% CI	OR[a]	95% CI	OR[a]	95% CI
Any complication	1.13	1.12–1.14	1.16	1.15–1.17	1.10	1.10–1.12
Colonic						
Perforation	1.07	1.00–1.15	1.26	1.09–1.52	1.04	0.88–1.24
Hemorrhage	1.28	1.27–1.30	1.36	1.33–1.39	1.23	1.22–1.26
Abdominal pain	1.07	1.05–1.08	1.10	1.08–1.11	1.04	1.02–1.05
Anesthesia-associated outcome						
Pneumonia	1.03	1.00–1.06	1.02	0.98–1.06	1.02	1.00–1.07
Infection	1.03	0.97–1.10	1.00	0.93–1.10	1.06	0.98–1.15
Complications secondary to anesthesia	1.15	1.05–1.28	1.19	1.04–1.37	1.10	0.96–1.20
Cardiopulmonary						
Hypotension	0.97	0.93–1.02	1.00	0.94–1.07	0.94	0.88–1.00
Myocardial infarction	0.98	0.95–1.01	0.98	0.94–1.02	0.98	0.94–1.03
Stroke and other central nervous system events	1.04	1.00–1.08	1.05	1.00–1.11	1.04	0.99–1.10

[a]Adjusted for age, sex, Charlson comorbidity status, polypectomy status, provider/practice type, region, and year (continuous).

any complication in all regions except the Southeast (Table 3). In the Southeast, there was no association between use of anesthesia services and complications from colonoscopy. In the Northeast region, where use of anesthesia services was most common, use of anesthesia services was associated with a 12% increased risk of any complication (adjusting for potential confounders). In the West, where use of anesthesia services was least common, the use of anesthesia services was associated with a 60% increased risk of any complication within 30 days of colonoscopy. When analyses were stratified by polypectomy status, we found no regional differences between the use of anesthesia services and the risk of any complication with colonoscopy.

Sensitivity Analysis

When we restricted analyses to inpatient-only diagnoses for reported outcomes, we found similar associations between use of anesthesia services overall and for each complication, with the exception of hemorrhage. We found no association between use of anesthesia services and inpatient diagnosis of hemorrhage.

Conclusions

Among insured patients completing a colonoscopy between 2008 and 2011, we found that the overall risk of adverse outcomes within 30 days of the procedure was higher among individuals who had received anesthesia services compared with individuals who had no indication of use of anesthesia services. We observed substantial regional variation in use of anesthesia services with colonoscopy and, importantly, variation in the risk of adverse outcomes by region. The increase in risk was greatest for patients in regions with a low prevalence of use of anesthesia services, even after adjusting for patient and procedure characteristics.

The most recent estimate of colonoscopies performed in the United States is from 2003, with an estimated 14.2

Table 3. Risk of 30-Day Overall Complication by Region of Service in the Calculation of ORs and 95% CIs of the Association Between Use of Anesthesia Services to Standard Sedation

Region	Prevalence of anesthesia use with colonoscopy	Overall		Polypectomy		No polypectomy	
		OR[a]	95% CI	OR[a]	95% CI	OR[a]	95% CI
Northeast	53.4%	1.12	1.10–1.14	1.12	1.09–1.16	1.11	1.08–1.13
Southeast	42.7%	1.00	0.99–1.02	1.07	1.05–1.10	0.95	0.93–0.97
Southwest	24.8%	1.26	1.23–1.28	1.20	1.16–1.24	1.30	1.27–1.35
Midwest	23.3%	1.24	1.22–1.26	1.27	1.23–1.30	1.21	1.19–1.24
West	7.8%	1.60	1.54–1.66	1.69	1.60–1.78	1.52	1.44–1.60
Unknown	39.6%	1.06	1.04–1.08	1.07	1.04–1.09	1.01	0.99–1.03

[a]Adjusted for age, sex, Charlson comorbidity status, polypectomy status, provider/practice type, and year (continuous).

million colonoscopies performed per year.[14,15] The use of colonoscopy increased among average-risk adults, bypassing stool-based tests.[16] However, screening colonoscopy is not without risks.[9,10] Results from our study show that some increased risks are associated with use of anesthesia services compared with colonoscopies performed without anesthesia services. Although we were not able to identify the actual agent used for sedation, the overwhelming majority of colonoscopies performed with anesthesia services in US clinical practice use propofol either alone or in combination with benzodiazepines and narcotics.

Although the use of anesthesia agents can directly impact colonoscopy outcomes, it is not solely the anesthesia agent that could lead to additional complications. In the absence of patient feedback, increased colonic-wall tension from colonoscopy pressure may not be identified by the endoscopist,[7,8] and, consistent with our results, could lead to increased risks of colonic complications, such as perforation and abdominal pain. We found no major differences in risk of any complication or specific complications associated with anesthesia services by polypectomy status, except for perforation, suggesting patient feedback could be important when tissue is removed.

In regards to anesthesia-associated harms, we detected a greater risk of complications secondary to anesthesia, but no increased risks associated with pneumonia or other infections. Prior research has not reported an increased risk of complications secondary to anesthesia with those who received anesthesia services, and these results should be replicated in other populations. Cooper et al[8] showed that use of anesthesia services was associated with an increased incidence of aspiration pneumonia compared with standard sedation (0.14% vs 0.10%; $P = .02$). Our results did not confirm the results from Cooper et al,[8] who examined complications using SEER–Medicare data, an older population with more comorbid conditions than our own younger population. It is possible that we were unable to detect these complications because they are rare in a younger population.

We included cardiovascular outcomes in our analysis and did not expect to find differences in risk of these rare conditions for individuals with and without anesthesia services. However, we detected a slightly higher risk of stroke and other central nervous system events overall with receipt of anesthesia services, adjusting for several confounders. Further studies are needed to evaluate the risk of stroke associated with use of propofol for colonoscopy. In particular, it is important to rule out potential confounding caused by use of anesthesia services in select high-risk patients before attributing the stroke risk to propofol.

By region, we showed that use of anesthesia services was associated with higher overall risks except for the Southeast region. The Southeast region has the second highest rate of use of anesthesia services with colonoscopy, and these findings suggest that there may be residual confounding by comorbidity status. That is, anesthesia services may be offered more widely to all patients in the Southeast region, compared with more selected use of anesthesia services in other regions. Our analyses adjusted for comorbidity using the Charlson score, and when we describe comorbid status by region, we did not find systematic differences in patient characteristics by anesthesia services across regions. In SEER–Medicare data, Khiani et al[4] determined that increasing comorbid associations was associated modestly (adjusted OR, 1.15) with increased use of an anesthesiologist with screening colonoscopy.

Our study used a large national claims-based analyses of colonoscopies in US insured adults aged 40–64 years. However, our results are not without limitations. First, our analyses of national claims-based data included a limited number of patient covariates that may have confounded the relationship between anesthesia services and colonoscopy complications. Still, we were able to adjust for the major confounders in the analysis, and our results generated new hypotheses that can be evaluated further in other study designs with access to more detailed confounder information. Second, we could not evaluate the sedative agent administered but rather the use of anesthesia services. Anesthesia services served as a proxy for the measure of exposure of the medication administered (ie, propofol) and the process of care associated with administration with an anesthesiologist or nurse anesthetist compared with standard sedation. Although we could not specifically identify propofol as the agent of use for anesthesia services, the medication administered by anesthesia professionals likely was propofol, given its preference by endoscopists.[17] Third, as with all claims data, there was the possibility of misclassification of outcomes based on the claim code. We would expect results of misclassification to be nondifferential by anesthesia use, and result in estimates close to the null. Finally, we did not have direct access to patient medical records to further clarify outcomes included in the analysis per ICD-9-CM codes, as was conducted by Levin et al.[11] With our limited data, we believe we have generated evidence for further research opportunities.

In conclusion, the overall risk of complications after colonoscopy is higher when individuals receive anesthesia services relative to those who receive standard sedation. The risk of colonoscopy is not without its own inherit risks, so the widespread adoption of anesthesia services with colonoscopy should be considered in the context of all potential risks.

References

1. Joseph DA, King JB, Miller JW, et al. Prevalence of colorectal cancer screening among adults–Behavioral Risk Factor Surveillance System, United States, 2010. MMWR Morb Mortal Wkly Rep 2012;61(Suppl):51–56.
2. Vargo JJ, Cohen LB, Rex DK, et al. Position statement: nonanesthesiologist administration of propofol for GI endoscopy. Gastroenterology 2009;137:2161–2167.
3. Liu H, Waxman DA, Main R, et al. Utilization of anesthesia services during outpatient endoscopies and colonoscopies and associated spending in 2003-2009. JAMA 2012;307:1178–1184.
4. Khiani VS, Soulos P, Gancayco J, et al. Anesthesiologist involvement in screening colonoscopy: temporal trends

and cost implications in the Medicare population. Clin Gastroenterol Hepatol 2012;10:58–64 e1.
5. Inadomi JM, Gunnarsson CL, Rizzo JA, et al. Projected increased growth rate of anesthesia professional-delivered sedation for colonoscopy and EGD in the United States: 2009 to 2015. Gastrointest Endosc 2010; 72:580–586.
6. Singh H, Poluha W, Cheung M, et al. Propofol for sedation during colonoscopy. Cochrane Database Syst Rev 2008;4:CD006268.
7. Wernli KJ, Inadomi JM. Anesthesia for colonoscopy: too much of a good thing? JAMA Intern Med 2013; 173:556–558.
8. Cooper GS, Kou TD, Rex DK. Complications following colonoscopy with anesthesia assistance: a population-based analysis. JAMA Intern Med 2013;173:551–556.
9. Dominitz JA, Baldwin LM, Green P, et al. Regional variation in anesthesia assistance during outpatient colonoscopy is not associated with differences in polyp detection or complication rates. Gastroenterology 2013; 144:298–306.
10. Klabunde CN, Potosky AL, Legler JM, et al. Development of a comorbidity index using physician claims data. J Clin Epidemiol 2000;53:1258–1267.
11. Levin TR, Zhao W, Conell C, et al. Complications of colonoscopy in an integrated health care delivery system. Ann Intern Med 2006;145:880–886.
12. Rutter CM, Johnson E, Miglioretti DL, et al. Adverse events after screening and follow-up colonoscopy. Cancer Causes Control 2012;23:289–296.
13. StataCorp. Stata Statistical Software: Release 12. College Station, TX: StataCorp LP, 2011.
14. Seeff LC, Richards TB, Shapiro JA, et al. How many endoscopies are performed for colorectal cancer screening? Results from CDC's survey of endoscopic capacity. Gastroenterology 2004;127:1670–1677.
15. U.S. Preventive Services Task Force. Screening for colorectal cancer: U.S. Preventive Services Task Force recommendation statement. Ann Intern Med 2008; 149:627–637.
16. Richardson LC, Tai E, Rim SH, et al. Vital signs: colorectal cancer screening, incidence, and mortality - United States, 2002-2010. MMWR Morb Mortal Wkly Rep 2011; 60:884–889.
17. Cohen LB, Wecsler JS, Gaetano JN, et al. Endoscopic sedation in the United States: results from a nationwide survey. Am J Gastroenterol 2006;101:967–974.

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Alison Brenner is currently at Sheps Center at UNC Chapel Hill, North Carolina and Carolyn Rutter is now at RAND Corporation, Santa Monica, California.

Conflicts of interest
The authors disclose no conflicts.

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