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Effect of patient-reported smoking status on short-term bariatric surgery outcomes

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Abstract
Introduction Preoperative patient screening is a major contributor to the remarkable safety of bariatric surgery. Smoking status is a modifiable patient risk factor, and smoking cessation is associated with improved outcomes in surgical patients. However, the length of smoking cessation necessary to optimize bariatric surgery patient outcomes is not yet defined. We sought to explore the relationship between patient-reported smoking status and short-term bariatric surgery outcomes.
Methods Using prospectively collected data from the MBSC registry, we evaluated the effects of patient-reported length of tobacco abstinence on 30-day surgical outcomes. Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy (SG) patients ($n = 49{,}772$) were divided into three categories based on smoking status: never smoker, former smoker, and recent smoker. We compared risk-adjusted complication rates using multivariable logistic regression models and compared excess body weight loss using a one-way ANOVA test.
Results The risk-adjusted rate of severe complications among RYGB patients in the recent smoker group was significantly increased relative to patients who had never smoked (OR 1.34; 95% CI, 1.01–1.77), but not among SG patients (OR 1.18; 95% CI 0.87–1.62). In the same populations, differences in overall complication rate were not significant for either RYGB (OR, 1.11; 95% CI 0.94–1.31) or LSG (OR 1.04; 95% CI 0.86–1.25).
Conclusions Recent smokers suffer detrimental effects of smoking on serious postoperative complications following RYGB surgery, but may not suffer an elevated risk of complications attributable to smoking for sleeve gastrectomy. An evaluation of the effect on long-term outcomes is necessary to further define the risks of smoking on bariatric surgery outcomes.

Keywords Bariatric surgery · Smoking · Outcomes · Patient reported

Bariatric surgery is the most effective treatment of morbid obesity. Several studies demonstrate that bariatric surgery leads to both greater and sustained weight loss in severely overweight patients when compared to non-surgical treatments [1–3]. Bariatric surgery is exceedingly safe because patients are appropriately screened for relevant medical and psychological factors [4–7]. Further improvement in bariatric surgery outcomes could be achieved by examining and minimizing risky patient behaviors. Smoking is one such modifiable behavior that is a relevant risk factor [8].

Although smoking cessation is associated with improved outcomes for surgical patients, the 'optimal' time interval between smoking cessation and bariatric surgery remains unknown [9]. Further, we rely on patient-reported timing of smoking cessation. However, the link between smoking status and increased complication rate in surgery patients is well described, and patients who quit smoking

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prior to surgery have a decreased complication burden [10]. Despite some concerns about short-term smoking cessation, the benefits of cessation prior to surgery are well established [11]. Nevertheless, these studies have failed to describe the length of abstinence from smoking that optimizes patient outcomes, which can only be ascertained by patient-reported means [12]. While data regarding patients' short-term postoperative complication rates following at least one year of preoperative smoking cessation exist, few studies have been performed specific to bariatric surgery [13–15]. Given the paucity of data to guide the length of tobacco abstinence, it remains difficult to make evidence-based recommendations regarding the perioperative management of morbidly obese smokers.

We utilized data from the Michigan Bariatric Surgery Collaborative (MBSC) to describe differences in 30-day complication incidence between three groups—patients who report never smoking, who report quitting smoking at least one year prior to surgery, and who had smoked within the year preceding surgery. We also evaluated the effects of these groups on additional postoperative outcomes, such as excess body weight loss.

Methods

Study sample

This study utilizes data from the Michigan Bariatric Surgery Collaborative (MBSC), a clinical registry that includes information from >95% of patients undergoing bariatric surgery in the state of Michigan. The MBSC has been described in detail in previous work [8, 16, 17]. This 39-hospital consortium employs trained data abstractors to perform extensive chart review regarding patient demographics, comorbidities, perioperative care and process details, and postoperative outcomes for a variety of bariatric surgery procedures. Member hospitals are annually assessed by central MBSC coordinators for accuracy and consistency. Institutional review boards at each member hospital have also approved data collection and participation in the MBSC.

We identified all patients in the MBSC registry undergoing primary Roux-en-Y gastric bypass (RYGB) or sleeve gastrectomy (SG) between June 2006 and May 2015. Patients undergoing revisional surgery were excluded from this analysis.

Outcomes

Our primary outcome for this study was 30-day complication rates, as determined by direct documentation of a surgical complication in the medical record or by evidence of a treatment specific to a complication. Complications were grouped by severity. Grade I complications are non-life-threatening, Grade II complications are potentially life-threatening, and Grade III complications are life-threatening and associated with residual and lasting disability. Grade II and III complications were grouped together as "severe complications." Grade I complications include surgical site infection (wound infections treated with antibiotics and/or wound opening), anastomotic stricture, bleeding (transfusion ≤4 units), pneumonia (if treated with antibiotics), hospital-acquired infections (UTI, *C. difficile* infection), and postoperative EGDs. Grade II complications include abdominal abscess formation (requiring drainage/reoperation), bowel obstruction/hernia (requiring operation), anastomotic leak, band-related problems (requiring reoperation), bleeding (transfusion >4 units), respiratory failure (requiring intubation for 2–7 days), renal failure (requiring in-hospital dialysis), wound infection/dehiscence, and VTE. Finally, Grade III complications include myocardial infarction/cardiac arrest, renal failure (requiring long-term dialysis), respiratory failure (requiring intubation for >7 days or tracheostomy), and death. The MBSC Endpoints Committee was responsible for grading any postoperative complications not unambiguously encompassed by these definitions. Additionally, we examined percent excess body weight loss (EBWL) at 1, 2, and 3 years after operation as a secondary outcome.

Independent variables

Smoking status was assessed based on patient responses to a preoperative MBSC survey. All included patients undergoing RYGB or SG were assigned to one of three categories based on their self-reported smoking status. "Never smoker" status was assigned to patients who report no history of tobacco use. "Former smokers" were the patients who report previously smoking tobacco, but quit at least 1 year before their operation. "Recent smokers" are those patients who report having quit between 3 months and one year prior to their operation. The 3-month lower bound of this range was dependent on the results of a survey sent to the practices participating in the Michigan Bariatric Surgery Collaborative asking about current policies regarding the minimum length patients must be smoke-free preoperatively. Data regarding demographic information (such as age, gender, insurance, BMI, and race) and comorbid conditions (such as diabetes, CVD, serious lung disease, prior hernia repair, or hypercholesterolemia) were collected for all patients via direct, clinical chart abstraction (Table 1).

Table 1 Baseline characteristics of participants by smoking status

	All	Never smoker	Former smoker	Recent smoker	*p* value
Patients (*n*)	49772	29257	16648	3853	
Procedure type (%)					
Roux-en-Y gastric bypass	49.8	49.1	54.3	36.3	<0.0001
Sleeve gastrectomy	50.2	50.9	45.7	63.7	<0.0001
Age, mean (±SD)	45.9 (±11.6)	44.9 (±11.6)	48.6 (±11.4)	42.4 (±10.5)	<0.0001
Gender (%)					
Female	78.0	79.0	76.1	79.0	<0.0001
Male	22.0	21.0	24.0	21.0	<0.0001
BMI, mean (±SD)	48.4 (±8.6)	48.5 (±8.6)	48.4 (±8.5)	48.3 (±8.5)	0.7239
Insurance type (%)					
Private	71.7	74.8	67.9	65.0	<0.0001
Race/ethnicity (%)					
White, Non-Hispanic	76.5	73.9	81.7	74.3	<0.0001
Black, Non-Hispanic	14.6	17.4	9.3	15.7	<0.0001
Other or multiracial	8.9	8.7	9.0	10.0	<0.0001
Risk factors (%)					
Diabetes	35.0	32.5	40.3	31.8	<0.0001
CVD	56.1	53.7	61.6	51.0	<0.0001
Hypertension	54.3	52.0	59.5	48.7	<0.0001
Serious CAD or PVD	11.8	9.5	15.8	11.5	<0.0001
Coronary artery disease	6.0	4.4	8.7	5.9	<0.0001
Serious lung disease	8.6	6.2	11.5	14.7	<0.0001
On cholesterol-lowering drug	25.0	22.5	29.9	23.9	<0.0001
Prior hernia repair	2.5	2.3	2.8	2.3	0.0010

BMI body mass index (calculated as kg/m^2), *CVD* cardiovascular disease, *CAD* coronary artery disease, *PVD* peripheral vascular disease

Statistical analysis

We utilized Pearson χ^2 tests for categorical variables (gender, insurance, etc.) and one-way ANOVA tests for continuous variables (age, BMI) to assess whether these patient characteristics were independent of the assigned smoking categorical variable. We then utilized Pearson χ^2 tests to assess whether there was an association between unadjusted complications and the assigned smoking categorical variable (for $p < 0.05$) for RYGB and sleeve gastrectomy, separately. For risk adjustment, we performed a stepwise logistic regression ($\alpha = 0.05$) for each complication with the following variables: procedure type (RYGB or SG), surgical approach (open, laparoscopic, or robot-assisted), gender, age at procedure, BMI at program start, insurance payer, cardiovascular disease (hypertension, peripheral vascular disease, or other cardiovascular disease), diabetes (type 1, type 2, insulin-dependent, or other), lung disease (serious disease or asthma), liver disease (non-alcoholic fatty liver disease or other), musculoskeletal disorder, psychological disorder (depression, anxiety, bipolar, or other), peptic ulcer disease, kidney failure, sleep apnea, urinary incontinence, venous thromboembolism, and the total number of comorbidities.

We included these risk-adjusted variables and the assigned smoking categorical variable in a multivariable logistic model as predictor variables, with the complication (yes or no) as the outcome of interest. From this, we obtained the statistical significance of the smoking status for predicting a given complication. All reported *p* values are 2-sided, and $p < 0.05$ was considered statistically significant. All statistical analyses were performed using SAS 9.4 64-bit.

Results

During the study period, 49,772 patients underwent primary RYGB or SG at 39 hospitals. Table 1 presents the baseline characteristics of participants by their smoking status—never smoker, former smoker, or recent smoker. Compared to the overall cohort, former smokers were

notable for being older (mean age 48.6 vs. 45.9), more likely to be male (24 vs. 22%), more likely to be Non-Hispanic White (82 vs. 76%), and more likely to have various comorbidities. Recent smokers were notably younger (mean age 42.4 vs. 45.9), more likely to undergo sleeve gastrectomy (64 vs. 50%), more likely to have serious lung disease (15 vs. 9%), and less likely to have private insurance (65 vs. 72%).

Table 2 shows the results of the risk-adjusted analyses. Among RYGB patients, recent smoker status was independently associated with the increased rate of serious complications as compared to never smoker status (5.4 vs. 2.9%; $p = 0.04$) (Fig. 1). The risk-adjusted rate of overall RYGB complications among former smokers was slightly lower than that of never smokers (10.5 vs. 11.5%, $p = 0.04$); while the overall complication rate among recent smokers was dramatically higher (14.3%), no statistical comparison between recent smoker and former smoker status was made. Despite the statistically significant differences in RYGB overall complication rate and

Table 2 30-day risk-adjusted postoperative complication rates by smoking status

	Never smoker		Former smoker		Recent smoker	
	Rate (%)	OR	Rate (%)	OR	Rate (%)	OR
Roux-en-Y gastric bypass						
Any complication	11.50	Ref.	10.54	0.92* (0.84–1.00)	14.34	1.11 (0.94–1.31)
Severe complication	2.89	Ref.	3.70	1.08 (0.93–1.25)	5.38	1.34* (1.01–1.77)
Medical complication	1.79	Ref.	1.85	0.95 (0.78–1.16)	2.31	1.10 (0.74–1.64)
Cardiac	0.20	Ref.	0.16	0.78 (0.41–1.47)	0.00	N/A (N/A)
Respiratory	1.30	Ref.	1.38	0.96 (0.76–1.21)	1.59	1.05 (0.66–1.66)
Renal	0.11	Ref.	0.16	1.07 (0.51–2.21)	0.18	1.32 (0.30–5.83)
Venous thromboembolism	0.39	Ref.	0.52	1.11 (0.95–1.30)	0.87	1.45 (0.72–2.94)
Surgical complication	8.33	Ref.	8.22	0.96 (0.87–1.06)	10.40	1.10 (0.91–1.34)
Hemorrhage	2.53	Ref.	3.41	1.11 (0.95–1.30)	3.27	1.15 (0.83–1.59)
Leak or perforation	0.62	Ref.	0.79	1.12 (0.82–1.53)	1.21	1.39 (0.78–2.49)
Anastomotic leak	0.46	Ref.	0.50	0.98 (0.67–1.42)	0.91	1.44 (0.71–2.90)
Wound complication	3.18	Ref.	3.10	0.94 (0.81–1.10)	4.97	1.25 (0.94–1.66)
Obstruction	2.72	Ref.	2.02	0.85 (0.72–1.02)	1.38	0.68 (0.46–1.02)
Small bowel obstruction	0.74	Ref.	0.94	1.09 (0.82–1.47)	0.73	0.95 (0.51–1.79)
Sleeve gastrectomy						
Any complication	5.25	Ref.	6.09	1.03 (0.91–1.16)	5.93	1.04 (0.86–1.25)
Severe complication	1.64	Ref.	1.67	0.96 (0.77–1.19)	2.38	1.18 (0.87–1.62)
Medical complication	1.07	Ref.	0.87	0.84 (0.63–1.11)	0.89	0.89 (0.57–1.39)
Cardiac	0.07	Ref.	0.12	1.21 (0.48–3.05)	0.09	1.20 (0.26–5.44)
Respiratory	0.61	Ref.	0.48	0.79 (0.54–1.15)	0.57	0.91 (0.51–1.62)
Renal	0.06	Ref.	0.08	0.98 (0.35–2.81)	0.11	1.34 (0.28–6.41)
Venous thromboembolism	0.47	Ref.	0.38	0.88 (0.57–1.36)	0.32	0.84 (0.42–1.68)
Surgical complication	2.71	Ref.	3.38	1.06 (0.90–1.25)	3.67	1.14 (0.89–1.45)
Hemorrhage	1.13	Ref.	1.51	1.02 (0.80–1.30)	1.62	1.20 (0.83–1.75)
Leak or perforation	0.33	Ref.	0.48	1.21 (0.79–1.86)	0.89	1.65 (0.93–2.92)
Anastomotic leak	0.01	Ref.	0.07	2.98 (0.48–18.53)	0.00	N/A (N/A)
Wound complication	0.79	Ref.	1.02	1.10 (0.82–1.48)	1.08	1.16 (0.75–1.81)
Obstruction	0.54	Ref.	0.41	0.84 (0.56–1.27)	0.28	0.71 (0.35–1.41)
Small bowel obstruction	0.10	Ref.	0.03	0.53 (0.17–1.63)	0.31	1.77 (0.57–5.47)

*$p < 0.05$ compared with risk-adjusted complication rate of never smoker. Variables included in risk adjustment model: procedure type (RYGB or sleeve gastrectomy), surgical approach (open, laparoscopic, or robot-assisted), gender, age at procedure, BMI at program start, insurance payer, cardiovascular disease (hypertension, peripheral vascular disease, or other cardiovascular disease), diabetes (type 1, type 2, insulin-dependent, or other), lung disease (serious disease or asthma), liver disease (non-alcoholic fatty liver disease or other), musculoskeletal disorder, psychological disorder (depression, anxiety, bipolar, or other), peptic ulcer disease, kidney failure, sleep apnea, urinary incontinence, venous thromboembolism, and total number of comorbidities

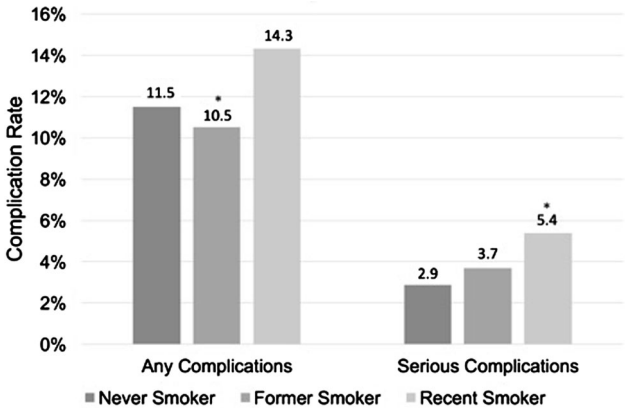

Fig. 1 Risk-adjusted gastric bypass 30-day complication rate by smoking status. *$p < 0.05$ compared with risk-adjusted complication rate of never smoker

serious complication rate, there was no statistically significant difference for any individual complications. Complication rates were not affected by smoking status in SG (Fig. 2).

Table 3 illustrates percent excess body weight loss (EBWL) at 1, 2, and 3 years postoperatively. At 2 years postoperatively, RYGB patients' EBWL varies with smoking status ($p < 0.05$). Never smokers and former smokers had the mean EBWL values of 69.7 and 70.0%, respectively, while recent smokers had a mean EBWL of 73.4%.

Discussion

This study reports a significant increase in the rate of 30-day serious perioperative complications among RYGB patients who report stopping smoking less than 1 year prior to surgery as compared to patients who report never smoking. Conversely, we did not identify a difference between these groups for patients who underwent SG. Further, RYGB patients who report stopping smoking over 1 year ago had no difference in outcomes compared to never smokers. Among RYGB patients, the risk-adjusted rate of serious complications for recent smokers was 5.4% as compared to 2.9% for patients who had never smoked. Additionally, a statistically significant decrease in the rate of all perioperative complications was observed among patients who quit smoking more than 1 year prior to surgery as compared to patients who had never smoked. Furthermore, an increased percent EBWL among patients who had smoked within 1 year prior to their operation was noted among both RYGB and SG patients.

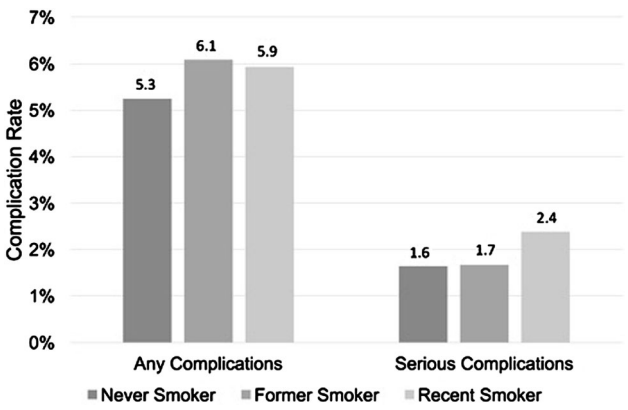

Fig. 2 Risk-adjusted sleeve gastrectomy 30-day complication rate by smoking status

Recent smokers have previously been shown to have an increased rate of complications following bariatric surgery [9, 15]. Our findings contribute to the literature by examining the effects of recent tobacco use as they relate to SG and by providing additional data on the prognosis of former smokers. Our data also show that patients who quit over 1 year prior to surgery achieve similar risk profiles as those patients who report never smoking. Livingston et al. found that former smokers with extensive smoking histories are at an elevated risk of short-term complications [15]. This discrepancy may be related to the lack of details regarding the intensity of patients' smoking (i.e., packs per day) in our study.

Past studies have found that SG is less likely to result in serious complications than RYGB [18, 19]. As the effect of smoking on perioperative outcomes is known to vary based on the specific procedure being performed, our analysis serves to inform surgeon decision-making regarding operative approach based on our finding that this difference in serious complication rate is accentuated by recent smoker status [20]. While smoking cessation as few as 4 weeks prior to surgery has been linked to decreased perioperative complications and longer duration of smoking cessation is known to magnify that effect, the optimal length of smoking cessation prior to surgery remains yet to be found [9, 21, 22]. Our findings suggest that as few as 3 months of smoking cessation may be sufficient for patients undergoing SG. However, RYGB patients may need at least 12 months of smoking cessation to achieve similar risk profiles as lifelong non-smokers.

With respect to weight loss, the literature remains conflicted on the nature of the relationship between EBWL and smoking [23, 24]. While our findings suggest that smoking during the year prior to bariatric surgery correlates with increased percent EBWL, it is important to note that the modest increase in EBWL is outweighed by the benefits of smoking cessation [25]. One possible explanation for the increased weight loss associated with recent smoker status at the time of bariatric surgery is that it is the result of the appetite-suppressing effects of nicotine due to

Table 3 Mean percent excess body weight loss at 1, 2, and 3 years postoperatively

	1 Year postoperatively			2 Years postoperatively			3 Years postoperatively		
	Mean (%)	SD (%)	*p* value (ANOVA)	Mean (%)	SD (%)	*p* value (ANOVA)	Mean (%)	SD (%)	*p* value (ANOVA)
RYGB									
Never smoker	67.5	17.9	0.11	69.7	19.6	0.01	67.2	19.5	0.14
Former smoker	67.4	18.3		70.0	19.8		66.2	34.6	
Recent smoker	69.3	19.2		73.4	20.4		70.0	20.1	
SG									
Never smoker	58.1	33.0	0.23	57.1	39.8	0.23	52.6	48.1	0.26
Former smoker	57.4	18.5		56.5	20.5		54.8	22.9	
Recent smoker	59.3	20.3		60.1	22.0		57.7	22.5	
N patients	21546			12803			8922		

RYGB Roux-en-Y gastric bypass, *SG* sleeve gastrectomy

postoperative resumption of smoking [26]. Placement of greater emphasis on the maintenance of smoking cessation in these patients may have lasting positive effects on their health.

This study has several limitations. First, the use of 30-day complication rates omits the impact of smoking on later postoperative complications that may occur such as marginal ulcers, hernias, stomach dilatation, and nutrient deficiencies [27]. However, this study informs an important risk discussion with patients about the short-term outcomes of their procedure. Second, we rely on patient-reported smoking cessation timing which may result in some inaccuracies. Nonetheless, this mimics our clinical practice. Unless a patient reports that he or she is an active smoker, confirmed with a urine cotinine test, we rely on patients to report their smoking status. Further, the timing of their abstinence is not readily testable using biochemical markers. This study provides some insight into the short-term outcomes in a real-world setting of patient-reported smoking status. Third, some patients' length of smoking cessation may be shorter than 3 months. While smoking status may be assessed by some practices via the use of a urine cotinine test, many practices rely on patient-reported smoking status. Urine cotinine testing can only reliably provide data about whether the patient has smoked in the last 3–4 days. There is currently no widely available or reliable means of testing for smoking beyond a week preoperatively. Inaccuracies in such data would bias the results toward the null, as such inaccuracies can reasonably be expected to consist only of patients reporting longer smoke-free times than is actually the case. Similarly, while the 12-month upper bound of preoperative smoking cessation was abstracted from patient medical records, the 3-month lower bound of this range was dependent on the results of a survey sent to the practices participating in the Michigan Bariatric Surgery Collaborative asking about current policies regarding the minimum length patients must be smoke-free preoperatively. Finally, additional details about patients' smoking history were not captured, such as pack-year history and precise duration (i.e., weeks/months) of smoking cessation. The MBSC is now capturing this information which will inform future studies.

These limitations notwithstanding, our findings demonstrate that a short duration of preoperative smoking cessation in RYGB patients is insufficient to neutralize the negative effects of smoking on the rate of serious perioperative complications. However, patients who quit smoking over 1 year preoperatively have similar risk profiles to those who have never smoked. Our findings also show that a duration of preoperative smoking cessation as short as 3 months may be sufficient for patients undergoing SG to minimize perioperative risk inherent to smoking. This study may inform continued efforts to determine the optimal length of smoking cessation prior to bariatric surgery. Furthermore, additional research to weigh marginal decreases in the rate of serious complications against the benefit of earlier bariatric surgery in morbidly obese patients may prove important.

Conclusions

This study from the Michigan Bariatric Surgery Collaborative shows a near elimination of the risk of smoking-related 30-day complication risk with a preoperative smoking cessation period of 1 year in patients undergoing

RYGB and 3 months in patients undergoing SG. With regard to optimizing perioperative outcomes, the minimum required length of preoperative smoking cessation should be no longer than 1 year for RYGB and 3 months for SG. Surgeons should emphasize the importance of prolonged smoking cessation on the reduction of short complications. Of course, this may be impractical in clinical practice and therefore these data could be used to better inform the preoperative surgeon–patient risk discussion. An evaluation of the effect on long-term outcomes is necessary to further define the risks of smoking on bariatric surgery outcomes.

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Compliance with ethical Standards

Disclosures Mr. Michael Inadomi, Rahul Iyengar, Ms. Ilana Fischer, Xing Chen and Emily Flagler all have no conflicts of interest or financial ties to disclose.

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