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RESEARCH

Postoperative pneumonia in elderly patients receiving acid suppressants: a retrospective cohort analysis

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ABSTRACT

Objective To test whether gastric acid suppressants are associated with an increased risk of postoperative pneumonia in patients undergoing elective surgery.

Design Population-wide retrospective cohort analysis.

Setting Canadian acute care hospitals between 1 April 1992 and 31 March 2008.

Patients Consecutive patients aged >65 years admitted for an elective operation.

Outcome measure Postoperative pneumonia recorded in inpatient postoperative notes.

Results A total of 593 265 patients were included, of whom about 21% were taking an acid suppressant (most commonly omeprazole or ranitidine). Overall, 6389 patients developed postoperative pneumonia, with a rate significantly higher for those taking acid suppressants (13 per 1000) than controls (10 per 1000), equivalent to a 30% increase in frequency (odds ratio 1.30 (95% confidence interval 1.23 to 1.38), P<0.001). However, no increase in risk was observed after adjustment for duration of surgery, site of surgery, and other confounders (odds ratio 1.02 (0.96 to 1.09), P=0.48). The general safety of acid suppressants extended to those patients prescribed proton pump inhibitors, experiencing long term treatment, receiving high doses, and undergoing high risk procedures.

Conclusion After adjustment for patient and surgical characteristics, acid suppressants are not associated with an increased risk of postoperative pneumonia among elderly patients admitted for elective surgery.

INTRODUCTION

Pneumonia is a common, serious, and potentially lethal complication following elective surgery. The incidence varies between 2% and 20% (depending on the patient population and the strategy used to diagnose pneumonia), is more common than cardiac complications in most settings, and collectively affects about a million surgical patients each year in North America.[1,2] Multiple clinical prediction rules have consistently identified several risk factors including patient age, duration of surgery, and site of surgery.[3] Overall, the case fatality rate is about 10% and the mean attributable increased length of hospital stay is about eight days.[4]

Gastric acid suppressants have become a focus of concern given their trade-off between reducing acid related upper gastrointestinal diseases yet inducing bacterial overgrowth of the stomach and oesophagus,[5,6] and therefore raising the risk of aspiration pneumonia.[7] Two large randomised trials in intensive care units observed that gastric acid suppressants led to a twofold to threefold increase in the incidence of ventilator associated pneumonia.[8,9] In contrast, recent analyses of outpatients yielded conflicting results about a potential increase in the incidence of community acquired pneumonia.[10-15] No large study has compared rates of postoperative pneumonia in patients receiving chronic gastric acid suppressants and in those not taking such medications.[16]

Published guidelines have called for more research on such potential risks since gastric acid suppressants are among the world's most commonly used medications and are sometimes available without prescription.[17-19] The purpose of this study was to test whether acid suppressants are associated with an increased risk of postoperative pneumonia. We examined acid suppressants as an entire group as well as distinguished by class (proton pump inhibitors, H_2 antihistamines, and miscellaneous agents). We focused on older patients because this group accounts for most major operative procedures, cases of postoperative pneumonia, and surgical deaths.

METHODS

Patient selection

We identified consecutive patients older than 65 years admitted for elective surgery in all Ontario hospitals between 1 April 1992 and 31 March 2008 through the Canadian Institutes for Health Information databases. These databases have been validated previously, and we used all 16 years available for analysis.[20-22] We did not include outpatients, those who had day surgery, or younger patients because of the low rate of pneumonia in these groups and the lack of available prescribing data. Patients who underwent multiple procedures were analysed according to first presentation so that each patient counted only once in each analysis. Our focus was on elective operations to ensure a cohort free of active pneumonia at the time

of inception. The study design was approved by the Sunnybrook Research Ethics Committee.

Acid suppressants

For each patient, we searched prescription records from the universal drug database for the year before admission, reasoning that these drugs would customarily be continued perioperatively. This assumption is in line with standard practices that recommend continuing acid suppressants (for those already receiving them) but not initiating acid suppressants prophylactically (for those not already receiving them).[23] We classified patients who received two or more prescriptions for an acid suppressant in the year before surgery (including at least one prescription in the 90 days before surgery) as receiving this drug on a chronic basis. Otherwise, we classified the patient as a control. This strategy assured that ascertainment was blinded, free of reverse causality bias, conservative in design, and congruent with prior research.[24]

Specific medications

We distinguished prescriptions according to drug, dose, and duration. The specific drugs were lansoprazole, omeprazole, pantoprazole, rabeprazole (proton pump inhibitors); cimetidine, famotidine, nizatidine, ranitidine (H_2 antihistamines); and aluminium hydroxide, misoprostol, and sucralfate (miscellaneous group). The dose was classified by separating those prescribed the median amount or less of each drug (such as omeprazole 20 mg) from those prescribed higher doses (such as omeprazole 40 mg). The duration of therapy was calculated from the date of the initial prescription and allowing up to a 120 day supply (based on prescribing practices in this region and uncertain patient adherence).[25] These methods were similar to those in recent studies linking acid suppressants to community acquired pneumonia.

Validating medications—Acid suppressants were generally available only by prescription in Canada during the study interval (oral antacids being the main exception). A prior validation study indicated that the prescription drug database has an accuracy rate of 99% when compared with pharmacy records.[26] Additionally, we tested for misclassification by using more expansive and restrictive definitions of medication exposure. The expansive definition included patients who had any prescription for an acid suppressant in the year before surgery. The restricted definition required four or more prescriptions for an acid suppressant in the year before surgery (with at least one in the 90 days before surgery). We also developed a "clearest case" analysis by analysing patients who stayed consistent with both expansive and restrictive definitions of medication use.

Pneumonia outcomes

The primary outcome was the development of pneumonia during a patient's hospital stay based on the full inpatient record and coded according to the international classification of diseases (ICD-9 codes 480.0 to 487.9 for years 1992 to 2002, and ICD-10 codes J10.0 to J18.9 for years 2002 to 2008). Surgical complications such as pneumonia are not always identified by clinicians, rigorously recorded in a patient's chart, or entered into databases. Hence, the codes are specific (about 98%) but not sensitive (about 35%).[27-30] We also conducted alternative analyses with wider and narrower codes for pneumonia. To validate our results and examine the more severe spectrum, we also considered complex combinations of outcomes—namely, patients who experienced postoperative pneumonia and had a prolonged stay in hospital (≥7 days), required admission to an intensive care unit, or died in hospital after surgery.

Risk factors

We measured the major predictors of postoperative pneumonia established in systematic reviews—namely, patient age, chronic obstructive lung disease, surgical site, duration of anaesthesia, ASA (American Society of Anesthesia) score, and use of a nasogastric tube. We estimated the duration of surgery from anaesthesia billing logs reported in 15 minute intervals using methods validated elsewhere.[31] Estimates of ASA scores that classify patients before surgery reflected anaesthesia billing and diagnoses in the year before surgery in accord with past research.[32] Use of a nasogastric tube was based on physician fee codes (G322, G355, G356, G357). The available databases did not contain reliable information on obesity, spirometry, radiology, current smoking status, or functional dependence.

Additional risk factors—We also gathered data on other factors associated with postoperative pneumonia in some studies.[33 34] We derived the patients' age, sex, and income quintile from the Ontario Registered Persons Database.[35] We identified drug therapy for lung disease at baseline by assessing prescriptions for an inhaled bronchodilator in the year before admission. We determined the use of other chronic treatments by searching for prescriptions for systemic corticosteroids, benzodiazepines, opioid analgesics, antipsychotics, antidepressants, and gastric motility agents in accord with prior research.[36] Comorbidities were based on the Charlson index.[37] Global counts of prior outpatient and inpatient care were based on measures under universal insurance.[38] We did not account for geographical location or characteristics of the hospital.

Statistical analysis

For the crude comparison, we used the χ^2 test to compare the frequency of postoperative pneumonia in those patients taking acid suppressants with those who were not taking acid suppressants. In the primary analysis we used multivariable logistic regression to adjust this comparison for patient and procedure factors, since the time of onset of pneumonia was not recorded. Propensity score matched analyses yielded nearly identical results to regression analysis and are not reported. We tested for selection bias through a secondary analysis of patients who had received an

Table 1 | Characteristics of patients aged >65 years admitted for elective surgery categorised by treatment with gastric acid suppressants (cases). Values are percentages unless specified otherwise

Characteristic	Cases (n=121 850)	Controls (n=471 415)
Mean (SD) age (years)	74.7 (6.1)	74.0 (6.0)
Female	55.0	47.4
Social status*:		
Lower	62.8	59.6
Higher	35.8	39.3
Missing	1.4	1.1
Past diagnoses:		
COPD	27.8	20.2
Asthma	12.6	8.6
Heart failure	14.9	9.9
Parkinson's disease	1.7	1.4
Pneumonia	13.1	9.0
Stroke	12.8	10.2
Chronic treatments:		
Systemic corticosteroid	5.3	2.1
Inhaled β agonist	8.2	4.4
Inhaled anticholinergic	4.1	2.1
Inhaled corticosteroid	8.5	4.6
Opioid analgesic	21.9	11.5
Benzodiazepine	25.8	13.2
Antipsychotic	2.2	1.4
Antidepressant	12.3	5.8
Gastric motility agent	8.2	1.2
Mean (SD) No of hospital visits in past 3 years:		
Outpatient visits	49.3 (33.4)	38.0 (26.7)
Inpatient admissions	1.0 (2.1)	0.6 (1.3)
Mean (SD) Charlson score	0.7 (1.4)	0.6 (1.4)
Type of surgery:		
Cardiac	9.7	9.2
Thoracic	2.6	2.5
Neurosurgical	1.8	1.6
Vascular	5.9	6.2
Musculoskeletal	22.7	19.1
Abdominal	26.0	23.8
Retroperitoneal	1.2	1.4
Lower urogenital	17.6	22.8
Breast and skin	4.7	5.5
External head and neck	2.8	3.3
Ophthalmological	4.7	4.4
Unclassified	0.3	0.3
Postoperative care†:		
Nasogastric tube	3.1	2.6
Hypoalbuminaemia	0.2	0.1
Mean (SD) ASA score‡	2.0 (0.7)	1.9 (0.7)
Mean (SD) duration of surgery (hours)	2.2 (1.5)	2.2 (1.5)

COPD=chronic obstructive pulmonary disease.
*Based on income quintile derived from the Ontario Registered Persons Database, dichotomised as the three lowest fifths and the two highest fifths.
†Derived from Ontario Health Insurance (OHIP) billing codes: codes G322, G355, G356, G357 for nasogastric tube; code 263 for hypoalbuminaemia.
‡ASA (American Society of Anesthesia) score ranges from 1 to 5, higher values indicating sicker patients.

acid suppressant in the past year but not in the 90 days before surgery. We tested further for hidden confounders in stratified analyses accounting for duration of use, specific medication, and relative dose.

RESULTS

During the 16 year interval a total of 955 914 elective operations were conducted on 593 265 patients involving 269 hospitals and 4195 surgeons. We observed no major trends over the years. The typical patient was 74 years old; underwent an abdominal, musculoskeletal, or lower urogenital operation; and had an average duration of anaesthesia of 132 minutes. Neurosurgical and retroperitoneal operations were the least common surgeries, yet still amounted to thousands of patients (9754 and 7911, respectively). The median length of stay was four days, about a quarter of patients (n=152 998) stayed in hospital more than a week, and 13% (n=74 222) were admitted to a critical care unit. Relatively few patients were hospitalised for pneumonia during the year before surgery (n=4812).

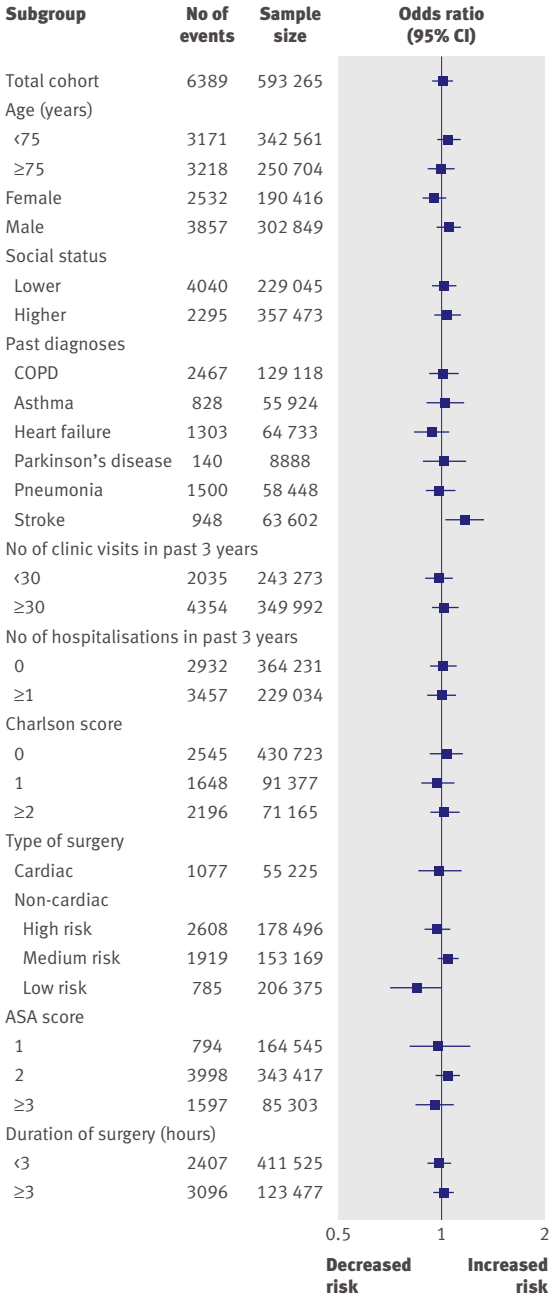
About 21% of patients (n=121 850) were taking an acid suppressant, and 79% (n=471 415) were not taking an acid suppressant before surgery. The two groups were similar in mean age, duration of surgery, and ASA scores (table 1). Multiple other risk factors for postoperative pneumonia were imbalanced against the acid suppressant group, including a history of chronic lung disease and prior pneumonia. Acute gastrointestinal bleeding was rarely diagnosed in the postoperative setting (n=226), particularly among patients receiving acid suppressants (odds ratio 0.73 (95% confidence interval 0.51 to 1.05)). The most commonly used acid suppressants were omeprazole (n=25 948) and ranitidine (n=45 531), and most patients (74%) had received treatment for several years before surgery.

Postoperative pneumonia was diagnosed in 6389 patients after surgery (roughly 11 per 1000). The frequency of this outcome was about a third higher among patients taking acid suppressants before surgery (13 per 1000) than among controls (10 per 1000) (odds ratio 1.30 (1.23 to 1.38), P<0.001). Accounting for age, sex, type of surgery, and duration of anaesthesia yielded a smaller increase in risk (odds ratio 1.20 (1.13 to 1.28)). Accounting for chronic lung disease, prior pneumonia, and hypoalbuminaemia yielded further attenuation (odds ratio 1.12 (1.05 to 1.19)). The final multivariable model, which adjusted for all baseline characteristics, showed no significant increase in the risk of postoperative pneumonia associated with acid suppressants (adjusted odds ratio 1.02 (0.96 to 1.09)).

The apparent safety of acid suppressants was evident across a variety of patient and procedure factors. Each analysis yielded no major increase in the risk of postoperative pneumonia, although the confidence intervals were broad in a few subgroups (figure). Overall, 11 of the 29 prespecified subgroups indicated a point estimate below 1.00, and 27 of the 29 prespecified subgroups showed a nominal P value >0.05. The findings were highly consistent among patients with different

ages, durations of surgery, and ASA scores, as well as those with a history of lung disease or prior pneumonia. All of the prespecified subgroups overlapped the 95% confidence interval of the main analysis, as did a post hoc subgroup analysis restricted to patients undergoing thoracic surgery (odds ratio 1.06 (0.88 to 1. 28)).

Our findings were consistent across different drug classes and doses of acid suppressants. Proton pump inhibitors (the most potent acid suppressants) were associated with no significant risk of postoperative pneumonia (adjusted odds ratio 0.97 (0.88 to 1.06)). Similarly, H_2 antihistamines also appeared safe (adjusted odds ratio 1.07 (0.98 to 1.17)), as did miscellaneous acid suppressants (adjusted odds ratio 1.13 (0.93 to 1.37)). Patients prescribed doses at or below the median showed no increase in the risk of postoperative pneumonia (adjusted odds ratio 1.03 (0.94 to 1.13)), nor did patients prescribed higher doses (adjusted odds ratio 1.01 (0.93 to 1.10)).



Association of postoperative pneumonia with taking acid suppressants in patients aged >65 years admitted for elective surgery, analyses for total cohort and subgroups. Odds ratios from adjusted multivariable analysis using logarithmic scale: result for total cohort is 1.02 (95% CI 0.96 to 1.09). (COPD=chronic obstructive pulmonary disease, ASA=American Society of Anesthesia)

We found no major anomalies related to duration of treatment. Patients treated for multiple years showed no significant increase in risk (adjusted odds ratio 1.01 (0.93 to 1.08)). Similarly, patients treated for a single year showed no significant increase (adjusted odds ratio 1.07 (0.96 to 1.19)). Patients (n=79 517) who were former users and had received an acid suppressant in the past (but none within the 90 days before surgery) showed no significant increase or decrease (adjusted odds ratio 1.01 (0.93 to 1.10)). Patients (n=28 975) who started an acid suppressant acutely before surgery (one prescription within 30 days of surgery and none earlier) showed no significant increase in risk (adjusted odds ratio 1.08 (0.97 to 1.20)).

We explored whether pneumonia was any more severe for patients receiving acid suppressants compared with those patients not receiving acid suppressants. For example, patients who developed pneumonia were about four times more likely than those who did not develop pneumonia to be admitted to an intensive care unit after surgery (54% *v* 12%, P<0.001). Similarly, patients who developed pneumonia were more likely than patients who did not develop pneumonia to stay in hospital more than a week (89% *v* 32%, P<0.001) or die during hospitalisation (18% *v* 1%, P<0.001). Acid suppressants were not associated with a significant increase in any of these severe forms of pneumonia (table 2). Overall, we observed a 12 day absolute increase in median length of stay for all patients who developed postoperative pneumonia (16 days *v* 4 days, P<0.001) and no differential increase for those receiving acid suppressants compared with controls.

As expected, other factors were significant predictors of postoperative pneumonia. The type of surgery was extremely important (table 3), with the highest risks observed for thoracic procedures and lowest risks for ophthalmological procedures. Duration of surgery was also important, equivalent to about a 1% relative increase in risk for each 2 minutes of time. Age, sex, insertion of a nasogastric tube, postoperative hypoalbuminaemia, and various comorbidities were each independent predictors (in accord with past research). The overall predictive accuracy of the 10 factors was strong (C statistic 0.81). All other baseline characteristics (listed in table 1) were not associated with a significant independent increase in risk, including gastric motility agents (adjusted odds ratio 1.07 (0.92 to 1.25)).

Table 2 | Association of pneumonia with taking gastric acid suppressants among patients aged >65 years admitted for elective surgery

	No of events	Sample size	Adjusted odds ratio (95% CI)*
Main analysis			
Any pneumonia	6389	593 265	1.02 (0.96 to 1.09)
Pneumonia plus death	1181	593 265	0.95 (0.81 to 1.10)
Pneumonia with admission to critical care unit	3460	593 265	1.05 (0.96 to 1.15)
Pneumonia with prolonged hospital stay†	5705	593 265	1.03 (0.96 to 1.10)
Alternative definitions			
Exposure to acid suppressants‡:			
Expanded definition	6389	593 265	1.02 (0.96 to 1.08)
Restricted definition	6389	593 265	1.05 (0.97 to 1.13)
Clearest case definition	5129	486 600	1.04 (0.96 to 1.12)
Pneumonia outcome§:			
Wide definition	42 719	593 265	1.02 (0.99 to 1.05)
Narrow definition	4331	593 265	1.04 (0.96 to 1.12)
Clearest case definition	4331	554 877	1.03 (0.95 to 1.11)

*Results from fully adjusted multivariate analysis accounting for all baseline characteristics.
†Hospital stay ≥1 week.
‡Definitions of exposure to acid suppressants: standard criteria ≥2 scripts; expanded criteria ≥1 script; restricted criteria ≥4 scripts; clearest case criteria, exposures defined by restricted criteria and non-exposures by expanded criteria.
§Definitions of pneumonia: wide criteria, diagnostic codes ICD-9 480.0–508.9 and ICD-10 J10.0–J22.9, J40.0–J70.9; narrow criteria, diagnostic codes ICD-9 481.0–486.9 and ICD-10 J13.0–J15.9; clearest case criteria, events defined by narrow criteria and non-events by wide criteria.

DISCUSSION

Overview

We studied elderly patients undergoing elective surgery over a 16 year interval. We found that pneumonia was a common complication, with more events in the few days after the operation than in the full year before the operation. The average case increased the length of hospital stay by more than 10 days and increased the patient's risk of death more than 10-fold. We also found that the type of patient prone to receive a gastric acid suppressant was also the type of patient predisposed to pneumonia. After accounting for patient and surgical risk factors, we found the risk of postoperative pneumonia was no higher with an acid suppressant compared with no acid suppressant. The apparent safety of acid suppressants was particularly evident for patients treated for multiple years, receiving proton pump inhibitors, prescribed high doses, and undergoing high risk surgical procedures.

Future research

The upper bound of almost all observed confidence intervals suggests that our study excludes a clinically important increase in risk with acid suppressants (estimated 1000 patients needed to be treated to potentially add one postoperative pneumonia case). Trial data are unlikely to overturn this result given the difficulties of recruiting patients into randomised studies in surgery and the obstacles of funding research on generic drugs. Moreover, our data imply that other risk factors are a greater priority for targeting interventions to reduce postoperative pneumonia risk; in particular, duration of surgery, antipsychotic medications, nasogastric tubes, and postoperative hypoalbuminaemia. Indirectly, our study also contrasts with recent research on the association between acid suppressants and pneumonia observed in non-surgical settings.[39-41]

Main limitation

The most important limitation of our study is that it is not a randomised trial that eliminates all confounding. However, the controlled nature of inpatient elective surgical services argues against major confounding from active smoking, ongoing alcohol consumption, reverse causality, or other confounders relevant to community acquired pneumonia.[42] The analyses, in addition, provided data on almost all major clinical predictors, and the results (tables 2 and 3) yield a pattern that is difficult to attribute to misclassification of pneumonia outcomes or medication exposures.[43] The main advantage of a randomised trial would be in prospective data collection to obtain more information about microbiology, radiology, medication compliance, clinical course, long term outcomes, milder

Table 3 | Potential predictors of postoperative pneumonia among 593 265 patients aged >65 years admitted for elective surgery

Characteristic	Adjusted odds ratio (95% CI)*
Age, per decade increase	1.54 (1.47 to 1.61)
Sex, men relative to women	1.29 (1.22 to 1.37)
Past diagnoses:	
COPD	1.48 (1.38 to 1.59)
Asthma	0.76 (0.69 to 0.83)
Heart failure	1.25 (1.16 to 1.35)
Parkinson's disease	1.36 (1.12 to 1.66)
Pneumonia	1.67 (1.55 to 1.79)
Chronic treatments:	
Systemic corticosteroid	1.16 (1.01 to 1.33)
Inhaled β agonist	1.18 (1.05 to 1.33)
Inhaled anticholinergic	1.21 (1.06 to 1.38)
Inhaled corticosteroid	1.24 (1.11 to 1.38)
Benzodiazepine	1.14 (1.06 to 1.30)
Antipsychotic	1.61 (1.34 to 1.92)
Antidepressant	1.18 (1.07 to 1.30)
Inpatient admissions, ≥1 in past 3 years	1.02 (1.01 to 1.03)
Charlson score, per unit increase	1.18 (1.16 to 1.19)
Type of surgery, relative to abdominal surgery:	
Cardiac	1.26 (1.14 to 1.38)
Thoracic	2.72 (2.46 to 3.00)
Vascular	1.38 (1.25 to 1.52)
Musculoskeletal	0.75 (0.69 to 0.82)
Lower urogenital	0.30 (0.26 to 0.34)
Breast and skin	0.21 (0.16 to 0.28)
Ophthalmological	0.07 (0.04 to 0.12)
Postoperative care:	
Nasogastric tube present	1.24 (1.12 to 1.38)
Hypoalbuminaemia present	5.74 (4.64 to 7.10)
Duration of surgery, per 30 minute increase	1.14 (1.13 to 1.14)

COPD=chronic obstructive pulmonary disease.
*Results from fully adjusted multivariate analysis accounting for all baseline characteristics.

WHAT IS ALREADY KNOWN ON THIS TOPIC

Postoperative pneumonia is a common and serious complication after major surgery in elderly patients

Several randomised trials have reported that gastric acid suppressants sometimes increase the risk of ventilator associated pneumonia in critical care unit patients

WHAT THIS STUDY ADDS

Patients who received gastric acid suppressants were predisposed to postoperative pneumonia but were also prone to independent risk factors for postoperative pneumonia

Some of the most important risk factors for postoperative pneumonia include a history of chronic obstructive pulmonary disease, heart failure, Parkinson's disease, or pneumonia; nasogastric tubes; and prescriptions of antipsychotics

Accounting for such differences in other risk factors reveals no direct association between gastric acid suppressants and a patient's risk of postoperative pneumonia

cases, and other evidence lacking in administrative databases.

Further limitations

Negative studies are sometimes prone to biases that differ from those in studies that report significant differences. Over-adjustment bias, for example, sometimes causes adjusted analyses to be less valid than crude analyses. This bias occurs if an event downstream in the course of a disease is mistakenly considered a baseline characteristic. Outcome heterogeneity can be a second potential bias if, for example, acid suppressants were to increase the risk of Gram positive bacterial pneumonia and decrease the risk of Gram negative pneumonia. In such circumstances, a comprehensive analysis might fail to detect either finding. Similarly, patient diversity can be a third bias if the same exposure is helpful to some patients and harmful to other patients, and the patient groups are hard to distinguish. We do not believe these three issues biased our results.

Relative advantages

One strength of our research relates to its statistical power, with a sample size almost double that of the US National Veterans Affairs Surgical Quality Improvement Program. The design allows the analyses to address the vagaries of ascertaining patient compliance since acid suppressants are not usually changed around elective surgical procedures.[44] The multicentred sampling provides a rigorous test free of referral bias or selective recruitment. The data also show that postoperative pneumonia diagnostic codes are specific (but not sensitive) given that our crude analysis yielded significant increase in risk similar to recent reports (and a base rate lower than surveillance reports). In addition, the statistical power corroborates other predictors of pneumonia reported in other studies, including use of benzodiazepines and nasogastric tubes.

Clinical relevance

The implication of our research is that the bacterial colonisation induced by gastric acid suppressants may be a major finding in laboratory experiments but may have little clinical importance for postoperative pneumonia,[45-49] so that concerns over the safety of acid suppressant therapy in the perioperative setting are perhaps misplaced. Minimising a patient's risk of postoperative pneumonia might be better prioritised through focusing on smoking cessation, optimising nutrition, reducing any psychoactive medications, prompt discontinuation of nasogastric tubes, chest expansion manoeuvres, and other opportunities for protecting the respiratory tract around the time of an operation.

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Competing interests: All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from DAR) and declare that all authors had: (1) no financial support for the submitted work from anyone other than their employer; (2) no financial relationships with commercial entities that might have an interest in the submitted work; (3) no spouses, partners, or children with relationships with commercial entities that might have an interest in the submitted work; (4) no non-financial interests that may be relevant to the submitted work.
Data sharing: No additional data available.

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