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Timing of nasogastric tube insertion and the risk of postoperative pneumonia: an international, prospective cohort study

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Abstract

Aim Aspiration is a common cause of pneumonia in patients with postoperative ileus. Insertion of a nasogastric tube (NGT) is often performed, but this can be distressing. The aim of this study was to determine whether the timing of NGT insertion after surgery (before versus after vomiting) was associated with reduced rates of pneumonia in patients undergoing elective colorectal surgery.

Method This was a preplanned secondary analysis of a multicentre, prospective cohort study. Patients undergoing elective colorectal surgery between January 2018 and April 2018 were eligible. Those receiving a NGT were divided into three groups, based on the timing of the insertion: routine NGT (inserted at the time of surgery), prophylactic NGT (inserted after surgery but before vomiting) and reactive NGT (inserted after surgery and after vomiting). The primary outcome was the development of pneumonia within 30 days of surgery, which was compared between the prophylactic and reactive NGT groups using multivariable regression analysis.

Results A total of 4715 patients were included in the analysis and 1536 (32.6%) received a NGT. These were classified as routine in 926 (60.3%), reactive in 461 (30.0%) and prophylactic in 149 (9.7%). Two hundred patients (4.2%) developed pneumonia (no NGT 2.7%; routine NGT 5.2%; reactive NGT 10.6%; prophylactic NGT 11.4%). After adjustment for confounding factors, no significant difference in pneumonia rates was detected between the prophylactic and reactive NGT groups (odds ratio 1.03, 95% CI 0.56–1.87, $P = 0.932$).

Conclusion In patients who required the insertion of a NGT after surgery, prophylactic insertion was not associated with fewer cases of pneumonia within 30 days of surgery compared with reactive insertion.

Keywords nasogastric tube, pneumonia, colorectal surgery, general surgery, pulmonary complications

What does this paper add to the literature?
While a number of studies have explored the role of routine insertion of a nasogastric tube (NGT) at the time of surgery, the timing of insertion after surgery has received little attention. This study found no significant difference in the rate of postoperative pneumonia between patients who received a NGT before or after the first episode of vomiting after elective colorectal surgery.

Introduction

Pneumonia is a common complication of major abdominal surgery, affecting up to 10% of patients and contributing to a 10-fold increase in the risk of mortality [1]. Pneumonia can occur through several mechanisms, including micro-aspiration during ventilated anaesthesia, aspiration of gastric contents during vomiting, poor expectoration due to immobility and pain and through transmission as a nosocomial infection. For patients undergoing surgery, pneumonia is distressing, since it is associated with considerable morbidity and an extended duration of hospital admission [2]. It is also burdensome for healthcare systems, and is associated with an additional cost of $10 000–$40 000 per patient in the United States [3–5].

Aspiration of gastric and intestinal contents may arise in patients with ileus after abdominal surgery. Insertion of a nasogastric tube (NGT) is a common management strategy, which aims to decompress the stomach and reduce the risk of vomiting. However, the procedure is

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distressing for patients, and may itself lead to vomiting through stimulation of the palatal 'gag' reflex. Enhanced recovery guidelines advise against the use of routine insertion of a NGT during surgery, but the timing of nonroutine NGT insertion still represents a common clinical dilemma. 'Prophylactic' insertion of a NGT in response to early signs of postoperative ileus, such as nausea and abdominal distension, may help to prevent vomiting and subsequent aspiration. 'Reactive' insertion in response to clear evidence of vomiting may minimize distress to patients through unnecessary use of a NGT, but may increase the risk of aspiration and its sequelae. Aspiration pneumonitis and pneumonia are frequent reasons for critical care admission after surgery, and are commonly life-threatening [6].

The aim of this study was to determine whether prophylactic insertion of a NGT (inserted before episodes of vomiting) compared with reactive insertion (inserted after episodes of vomiting) confers any clinical benefit with respect to the development of pneumonia.

Method

Ethics and governance

This was a preplanned secondary analysis of the Ileus Management International (IMAGINE) study (https://www.researchregistry.com/) (UIN 3072). Study approvals were sought according to country-specific procedures, and the current results are reported in line with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [7]. The study protocol has been published previously [8] and the methods are briefly summarized herein.

Study design

A prospective, multi-centre, observational study was delivered by a student- and trainee-led collaborative group with a track record of international research [9]. All hospitals performing elective colorectal surgery in Europe, Australasia and South Africa were invited to contribute to the study. Participating hospitals enrolled patients in blocks of 14-day data collection periods between January and April 2018. A data validation exercise, comprising measures of data accuracy and case ascertainment, was preplanned in at least 10% of participating centres and has been reported in the main analysis elsewhere [10].

Eligibility criteria

All patients undergoing elective colorectal resection were eligible. Elective procedures were defined as those with a planned admission. Procedures performed via open or minimally invasive surgery for any indication were included. Procedures performed trans-anally or for primary hepatobiliary, vascular, gynaecological or urological pathologies were excluded. Elective appendicectomy was not eligible, unless a more extensive resection was planned.

Outcome measures

In this additional planned analysis, the main outcome of interest was the incidence of postoperative pneumonia within 30 days of surgery, confirmed radiologically in accordance with local clinical practice at included centres. The management and time to resolution of pneumonia were not considered. Other outcomes of interest were postoperative complications occurring within 30 days of surgery, classified using the Clavien–Dindo scale (grade 0, no complication; grades 1–2, minor complication; grades 3–5, major complication) [11]. This was used to classify the highest-ranking complication experienced by each patient. Since ileus was measured using the GI-2 outcome, rather than being considered as a complication, its sequelae (including insertion of a NGT) were not assigned a Clavien–Dindo grade.

Definition of groups

Patients treated with a NGT were divided into three groups defined by the time at which the NGT was inserted. Those in whom a NGT was inserted on the same day as surgery were classified as the 'routine' NGT group. The remaining patients were divided based on the timing of insertion relative to the first episode of vomiting. Those who received a NGT before the first episode were classified as the 'prophylactic' NGT group. Those in whom it was inserted after the first episode were classified as the 'reactive' NGT group. The timing of NGT insertion and vomiting were recorded to the nearest day, so where both occurred on the same day it was not possible to determine the order of events. Such cases were considered in the reactive NGT group because even if the NGT was inserted before vomiting the timing was too late to prevent vomiting, thus representing a failure of treatment.

Enhanced recovery after surgery (ERAS) protocols

ERAS compliance was determined at a centre level at the time of surgery. Each centre was assessed on 17 components from the 22 that are included within published colorectal guidelines [12]. Where the majority of

cases (> 50%) routinely satisfied a component, the centre was deemed to have high compliance with respect to that component, scoring one point. The total number of points for a centre were then added across all components to give an 'ERAS compliance score', with the maximum possible score being 17 points.

Statistical methods

Initially, a range of demographic and treatment-related factors were compared between the groups using Fisher's exact test for nominal variables and the Mann–Whitney *U*-test for ordinal or continuous variables. Patient outcomes were then assessed using the same approach. Pneumonia rates were additionally analysed using a Kaplan–Meier approach, to account for the time at which this developed, relative to NGT insertion. Patients who developed pneumonia prior to NGT insertion were assigned a time of zero, and patients were censored at death or after 30 days of follow-up. The groups were compared using a log-rank test.

Multivariable analyses were performed to assess the association between the timing of NGT insertion and pneumonia, after adjusting for the effects of potentially confounding factors. Prior to the analysis, continuous variables were divided into categories in order to improve model fit. The timing of NGT was then entered into a multivariable binary logistic regression at the first step, with a backwards stepwise approach (using $P > 0.1$ as a criterion for removal) used to select other factors that were significant independent predictors of pneumonia.

An intention-to-treat analysis of routine NGT versus no routine NGT was also performed, in which those patients who had a NGT inserted on the same day as surgery (i.e. the 'routine NGT' group) were compared with the remainder of the cohort for whom no 'routine NGT' was inserted (including no NGT, prophylactic NGT and reactive NGT). Analyses were repeated using the previously described approach.

All analyses were performed using IBM SPSS 22 (IBM Corp., Armonk, New York, USA), with $P < 0.05$ deemed to be indicative of statistical significance throughout.

Results

Study setting

Data were available for 4721 patients from 422 centres in 27 countries. The median ERAS compliance score per centre was 13 out of 17 measured components [interquartile range (IQR) 10–15]. Only 60 centres (14.2%) showed full compliance across all components.

Study cohort

Pneumonia status was unknown in six patients, and these were excluded from the analysis. Of the remaining 4715 patients, a NGT was inserted in 1536 (32.6%), of whom 926 (60.3%) were routine, 461 (30.0%) reactive, and 149 (9.7%) prophylactic. In total, 4.2% (200/4715) of patients developed pneumonia within 30 days of surgery, with rates found to differ significantly between groups ($P < 0.001$). The rates of pneumonia were lowest in the no NGT ($n = 86/3179$, 2.7%) and routine NGT ($n = 48/926$, 5.2%) groups and highest in the reactive ($n = 49/461$, 10.6%) and prophylactic ($n = 17/149$, 11.4%) NGT groups (Fig. 1).

Prophylactic versus reactive NGT insertion

For patients in the prophylactic NGT group ($n = 149$), the median postoperative day of insertion was day 4 (IQR 3–5), with 20 (13.4%) subsequently vomiting in the days after NGT insertion. For the reactive NGT group ($n = 461$), the median postoperative day of insertion was day 3 (IQR 3–5). Of these, 250 (54.2%) vomited at least 1 day before the NGT was inserted, with the remainder ($n = 211$, 45.8%) vomiting on the same day.

The demographics of patients treated with prophylactic and reactive NGT are reported in Table 1. The two groups were similar, with the exception of the prophylactic group having a significantly higher proportion of patients with ischaemic heart disease [$n = 30/149$ (20.1%) *vs* $n = 51/461$ (11.1%); $P = 0.008$]. There was also a significant difference in pathology between the groups ($P = 0.042$), with prophylactic NGT being more common in patients with diverticular disease or malignancy. Intra-operative factors and postoperative treatment were similar between groups (Table 2).

Rates of pneumonia did not differ significantly between the two groups in univariable analysis, developing in 11.4% ($n = 17/149$) of those treated with prophylactic NGT insertion and 10.6% ($n = 49/461$) of those treated with reactive NGT insertion ($P = 0.763$). Comparisons of the timing of pneumonia diagnosis relative to NGT insertion found similar distributions in both groups ($P = 0.501$; Fig. 2). Specifically, the proportions of patients developing pneumonia after NGT insertion were 6.0% ($n = 9/149$) *vs* 6.1% ($n = 28/461$) in the prophylactic and reactive NGT groups, respectively. Analysis using a Kaplan–Meier approach also showed similar pneumonia rates across both groups ($P = 0.781$; Fig. 3).

Of the other outcomes considered, prophylactic and reactive NGT groups had similar lengths of hospital stay

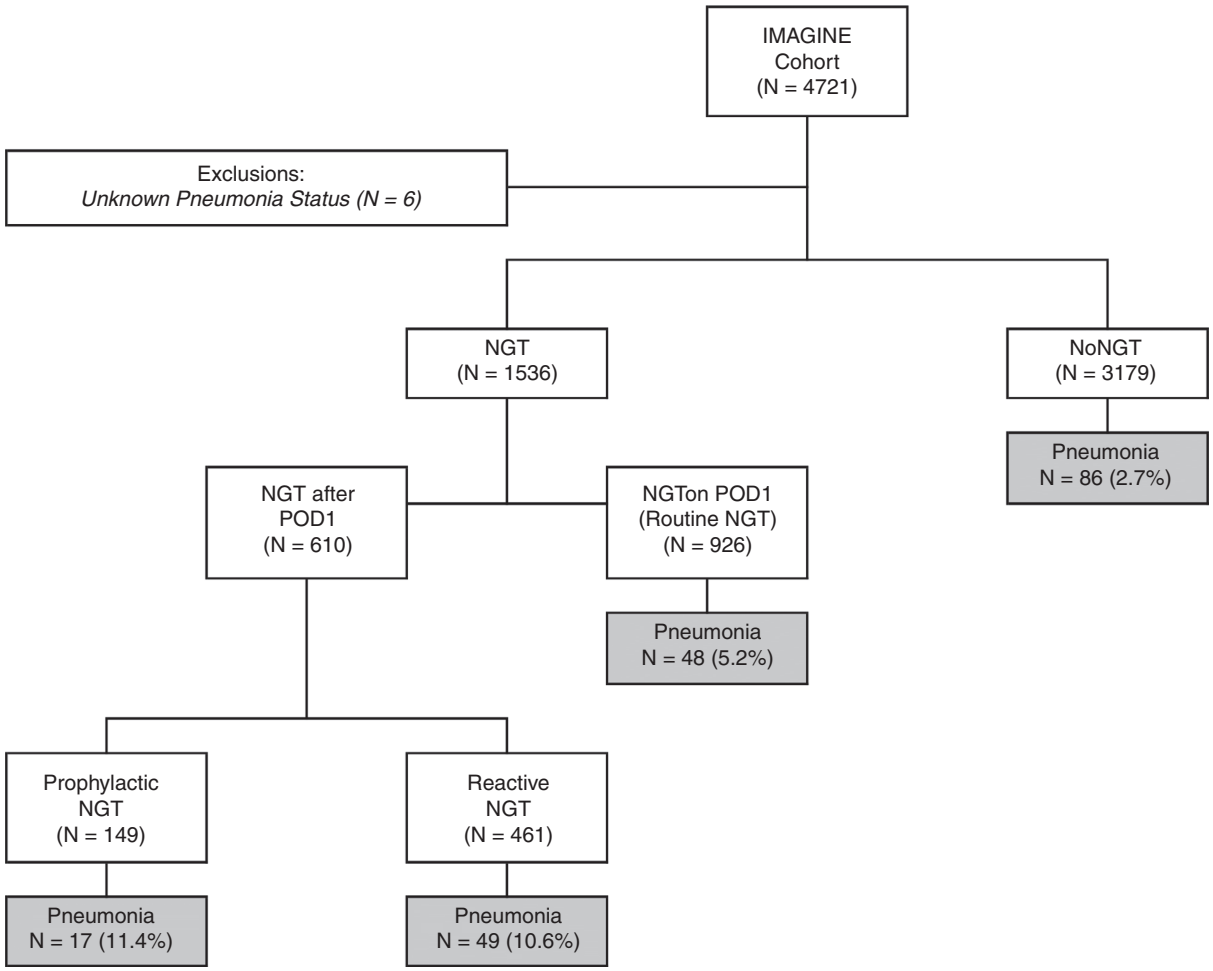

Figure 1 Study flowchart. NGT, nasogastric tube; POD, postoperative day.

(median 13 *vs* 13 days; $P = 0.788$) and rates of readmission within 30 days [$n = 12/149$ (8.1%) *vs* $n = 49/458$ (10.7%); $P = 0.433$, Table 2]. However, a significant difference in Clavien–Dindo grade was found ($P = 0.036$), which is visualized in Fig. 4. The proportions of patients with no complications [$n = 26/149$ (17.4%) *vs* $n = 77/460$ (16.7%)] and grade 1 complications [$n = 30/149$ (20.1%) *vs* $n = 88/460$ (19.1%)] were similar in the prophylactic and reactive NGT groups, as were the rates of grade 5 complications [i.e. in-hospital mortality: $n = 7/149$ (4.7%) *vs* $n = 18/460$ (3.9%)]. However, the reactive NGT group had a higher rate of grade 2 complications [$n = 183/460$ (39.8%) *vs* $n = 29/149$ (19.5%)], whilst grade 3 [$n = 38/149$ (25.5%) *vs* $n = 74/460$ (16.1%)] and grade 4 [$n = 19/149$ (12.8%) *vs* $n = 20/460$ (4.3%)] complications were more common in the prophylactic NGT group.

Multivariable models were produced to assess the association between the timing of NGT and pneumonia rates, after accounting for other confounding factors. Initially, all factors from Table 1 as well as the intra-operative and postoperative treatment factors from Table 2 were considered for inclusion in the model. This identified increasing patient age ($P = 0.018$) and use of postoperative intravenous patient-controlled analgesia (PCA) ($P = 0.007$) to be independently associated with a significantly increased risk of pneumonia (Table 3). After accounting for these factors, the difference in pneumonia rates between reactive and prophylactic NGT remained nonsignificant (odds ratio 1.03, 95% CI 0.56–1.87; $P = 0.932$).

Intention to treat analysis of routine NGT insertion

An additional analysis was performed to assess a second research question, namely the impact of routine NGT insertion on patient outcomes. This was analysed using an intention-to-treat approach. As such, patients with

Table I Demographics by timing of nasogastric tube (NGT) insertion.

		Timing of NGT insertion		
	Total (*N*)	Prophylactic	Reactive	*P*-value
Age (years)	610	71 (60–79)	69 (59–77)	0.127
Sex (% male)	610	107/149 (71.8%)	294/461 (63.8%)	0.075
BMI (kg/m^2)				
< 18.5	608	1/149 (0.7%)	13/459 (2.8%)	0.482*
18.5–24.9		57/149 (38.3%)	144/459 (31.4%)	
25.0–30.0		54/149 (36.2%)	181/459 (39.4%)	
> 30.0		37/149 (24.8%)	121/459 (26.4%)	
Current smoker	610	28/149 (18.8%)	67/461 (14.5%)	0.242
ASA				
1	610	10/149 (6.7%)	40/461 (8.7%)	0.058*
2		73/149 (49.0%)	254/461 (55.1%)	
3		60/149 (40.3%)	158/461 (34.3%)	
4–5		6/149 (4.0%)	9/461 (2.0%)	
Previous abdominal surgery	610	56/149 (37.6%)	188/461 (40.8%)	0.502
Existing stoma				
No	609	137/149 (91.9%)	421/460 (91.5%)	0.298
Ileostomy		3/149 (2.0%)	20/460 (4.3%)	
Colostomy		9/149 (6.0%)	19/460 (4.1%)	
History of IHD	610	30/149 (20.1%)	51/461 (11.1%)	**0.008**
History of PAD	610	10/149 (6.7%)	24/461 (5.2%)	0.538
History of COPD	610	14/149 (9.4%)	40/461 (8.7%)	0.743
History of DM				
No	610	114/149 (76.5%)	387/461 (83.9%)	0.082
Diet/tablet controlled		28/149 (18.8%)	63/461 (13.7%)	
Insulin controlled		7/149 (4.7%)	11/461 (2.4%)	
ERAS compliance score				
< 12	599	18/148 (12.2%)	68/451 (15.1%)	0.626*
12–13		28/148 (18.9%)	87/451 (19.3%)	
14–15		56/148 (37.8%)	121/451 (26.8%)	
16+		46/148 (31.1%)	175/451 (38.8%)	
Pathology				
Diverticular disease	610	7/149 (4.7%)	11/461 (2.4%)	**0.042**
Inflammatory bowel disease		15/149 (10.1%)	47/461 (10.2%)	
Malignancy		123/149 (82.6%)	364/461 (79.0%)	
Other benign		4/149 (2.7%)	39/461 (8.5%)	

Total *N* represents the total number of patients included in each analysis, after excluding those with missing data for the stated variable. Data are reported as *n*/*N* (%), with *P*-values from Fisher's exact tests, or as median (interquartile range), with *P*-values from Mann–Whitney *U*-tests, unless stated otherwise. Bold *P*-values are significant at $P < 0.05$.

ASA, American Society of Anesthesiologists; BMI, body mass index; COPD, chronic obstructive pulmonary disease; DM, diabetes mellitus; ERAS, enhanced recovery after surgery; IHD, ischaemic heart disease; PAD, peripheral arterial disease.

**P*-value from Mann–Whitney *U*-test, as the factor is ordinal.

NGTs inserted on the same day as surgery (i.e. the 'routine NGT' group, $n = 926$) were compared with the remainder of the cohort (i.e. the 'no NGT', 'reactive NGT' and 'prophylactic NGT' groups, $n = 3789$). Analysis of patient demographics (Table S1) found several significant differences between groups, with the routine NGT group having a significantly higher American Society of Anesthesiologists grade ($P < 0.001$) and being more likely to have a history of abdominal surgery ($P < 0.001$), ischaemic heart disease ($P = 0.003$), peripheral arterial disease ($P = 0.007$) or chronic obstructive pulmonary disease ($P = 0.047$) than the remainder of the cohort. Routine use of a NGT was also significantly more common at centres with lower ERAS compliance scores ($P < 0.001$), after open surgery ($P < 0.001$) and after left colonic resection

($P = 0.034$). The postoperative course also differed between groups, with routine NGT insertion being associated with higher rates of epidural catheters and red blood cell transfusion, but lower rates of intravenous PCA and wound catheters, as well as a longer length of stay ($P < 0.001$ for all comparisons; Table S2).

Rates of pneumonia were not found to differ significantly between the two groups on univariable analysis, developing in 5.2% ($n = 48/926$) of those with routine NGT insertion, compared with 4.0% ($n = 152/3789$) in the remainder of the cohort ($P = 0.122$). This effect remained nonsignificant on multivariable analysis (Table S3), with an adjusted odds ratio of 1.37 (95% CI 0.95–1.98; $P = 0.095$).

Discussion

This was an additional analysis of a large, observational study exploring bowel function after elective colorectal surgery. We found the incidence of routine insertion of a NGT to be high, at 19.6% ($n = 926/4715$) of the cohort as a whole, despite current guidance advising against this practice [12]. Whilst the numbers of patients with pneumonia were small, there were no apparent differences in the rates of pneumonia between

Table 2 Intra- and postoperative factors by timing of nasogastric tube (NGT) insertion.

	Total (*N*)	Timing of NGT insertion		*P*-value
		Prophylactic	Reactive	
Intra-operative factors				
Operative approach				
Minimally invasive	610	78/149 (52.3%)	243/461 (52.7%)	1.000
Open		56/149 (37.6%)	172/461 (37.3%)	
Converted to open		15/149 (10.1%)	46/461 (10.0%)	
Resection type				
Colonic – right	610	59/149 (39.6%)	185/461 (40.1%)	0.443
Colonic – left		25/149 (16.8%)	60/461 (13.0%)	
Rectal		56/149 (37.6%)	172/461 (37.3%)	
Total		9/149 (6.0%)	44/461 (9.5%)	
Formation of new stoma				
No	610	91/149 (61.1%)	276/461 (59.9%)	0.577
Ileostomy		32/149 (21.5%)	116/461 (25.2%)	
Colostomy		26/149 (17.4%)	69/461 (15.0%)	
Postoperative treatment (on days 1–10)				
Epidural catheter	609	35/149 (23.5%)	112/460 (24.3%)	0.912
IV PCA	609	80/149 (53.7%)	216/460 (47.0%)	0.158
Wound catheter	609	14/149 (9.4%)	29/460 (6.3%)	0.201
RBC transfusion	610	24/149 (16.1%)	54/461 (11.7%)	0.161
Patient outcomes				
Pneumonia	610	17/149 (11.4%)	49/461 (10.6%)	0.763
Length of stay (days)	606	13 (9–20)	13 (10–18)	0.788
Readmission (within 30 days)	607	12/149 (8.1%)	49/458 (10.7%)	0.433
Clavien–Dindo grade				
No complications	609	26/149 (17.4%)	77/460 (16.7%)	**0.036***
Grade 1		30/149 (20.1%)	88/460 (19.1%)	
Grade 2		29/149 (19.5%)	183/460 (39.8%)	
Grade 3		38/149 (25.5%)	74/460 (16.1%)	
Grade 4		19/149 (12.8%)	20/460 (4.3%)	
Grade 5 (death)		7/149 (4.7%)	18/460 (3.9%)	

Total *N* represents the total number of patients included in each analysis, after excluding those with missing data for the stated variable. Data are reported as *n*/*N* (%), with *P*-values from Fisher's exact tests, or as median (interquartile range), with *P*-values from Mann–Whitney *U*-tests, unless stated otherwise. Bold *P*-values are significant at $P < 0.05$.

IV PCA, intravenous patient-controlled analgesia; RBC, red blood cell.

**P*-value from Mann–Whitney *U*-test, as the factor is ordinal.

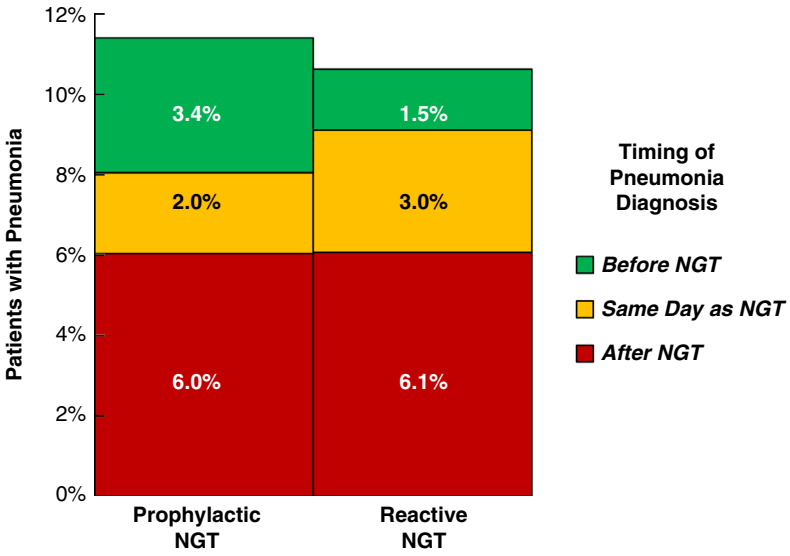

Figure 2 Timing of pneumonia by timing of nasogastric tube (NGT) insertion.

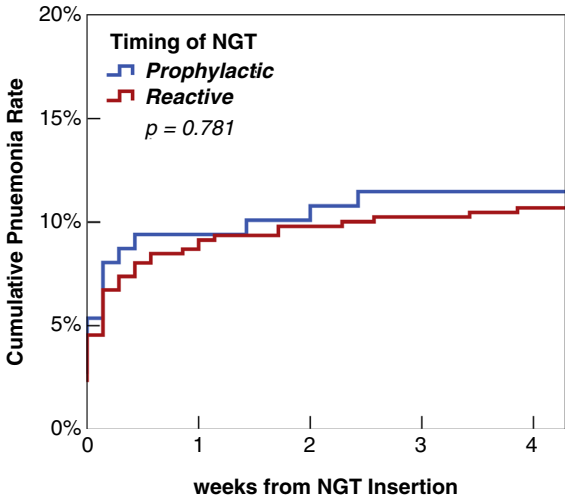

Figure 3 Kaplan–Meier curve of pneumonia by timing of nasogastric tube (NGT) insertion. Cases of pneumonia occurring prior to, or on the day of NGT insertion were assigned a time of zero. Patients were censored at the date of death, or at 30 days after NGT insertion. The *P*-value is from a log-rank test.

patients receiving a NGT before (prophylactic) or on the same day/after the first episode of vomiting (reactive). This remained true after adjustment for confounding factors. Although the overall proportion of patients with complications was similar, the distribution of Clavien–Dindo grades in unadjusted data differed between groups, with a preponderance of minor complications (grade 2) in the reactive NGT group but a greater proportion of major complications (grades 3–4) in the prophylactic NGT group.

The use of a NGT after abdominal surgery is a common topic of debate. Routine insertion of a NGT is discouraged by ERAS guidelines because it is associated with delayed recovery, reduced postoperative mobility and increased adverse events such as pharyngo-laryngitis [12,13]. Their management is also a source of considerable distress to patients [14]. On the other hand, NGTs can play an important role after surgery, particularly in the context of delayed gut function and the risk of respiratory complications, such as aspiration pneumonia. This is commonly fatal, with some reports suggesting a mortality rate of up to 27% in high-risk patients [6]. In the present study, no association between the timing of postoperative NGT insertion and the development of pneumonia was found, but prophylactic insertion was unexpectedly associated with an increase in other major complications. We hypothesize that this may be due to a selection bias, in that the patient groups deemed to be at highest risk of ileus (e.g. those who are more frail or undergoing longer or more complex surgery) were selected for prophylactic insertion. It may also have resulted from patients requiring admission to critical care for other reasons. In this setting, a NGT may be inserted as a precautionary measure if a more turbulent postoperative course is expected. However, since no data were available regarding frailty or critical care admissions, and no further information was available regarding the timing or details of complications other than the Clavien–Dindo grade, it was not possible to

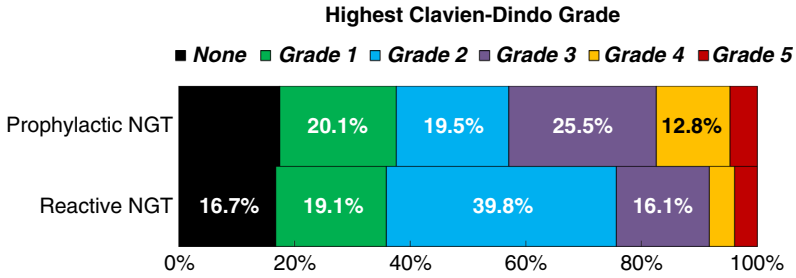

Figure 4 Clavien–Dindo complication grades by timing of nasogastric tube (NGT) insertion. Unlabelled bars each make up < 5% of cases.

Table 3 Multivariable analyses for factors associated with postoperative pneumonia.

	Odds ratio (95% CI)	*P*-value
Timing of NGT (reactive*)	1.03 (0.56–1.87)	0.932
Age (years)		**0.018**
< 60	–	–
60–69	2.51 (1.03–6.10)	**0.043**
70–79	2.74 (1.18–6.39)	**0.020**
80+	4.19 (1.73–10.15)	**0.002**
IV PCA	2.13 (1.23–3.67)	**0.007**

Results are from a multivariable binary logistic regression, with the timing of NGT entered at the first step, before using a backwards stepwise approach to select independent predictors of pneumonia. All of the factors from Table 1, as well as the intra-operative and postoperative treatment factors from Table 2 were considered for inclusion in the model, and only those selected by the stepwise procedure are reported in the table. Patient age was divided into categories, prior to analysis, in order to improve model fit. Bold *P*-values are significant at $P < 0.05$.

IV PCA: intravenous patient-controlled analgesia; NGT, nasogastric tube.

*Relative to prophylactic.

test this hypothesis further. It is unlikely that the cause of this association is directly attributable to the timing of NGT insertion, but rather more likely to be attributable to the reason why it was indicated.

A large body of evidence has explored the role of routine NGT insertion at the time of surgery. The proposed aims of this have included: to accelerate the return of gut function; to provide preemptive relief from vomiting and abdominal distension; to prevent respiratory complications after surgery; and to reduce the risk of anastomotic dehiscence. A number of studies, including the results of a Cochrane systematic review, have since discounted these proposals, and other studies have raised concerns over an apparent increase in related adverse events [13,15]. This has led to a change in enhanced recovery guidelines, with many surgeons abandoning the practice in favour of selective insertion of a NGT after surgery [12,16]. Nevertheless, in this study, a high proportion of NGTs were inserted routinely. The reason for this is unclear, but may relate to sub-optimal uptake of enhanced recovery guidelines or genuine clinical need owing to intra-operative complications. It is possible that some NGTs were inserted as a precaution, which may be acceptable if the risks are duly balanced, but is limited by heterogeneous perceptions of risk amongst surgeons. When routine NGT insertion was compared with non-routine in the present study, the adjusted effect estimate for pneumonia (OR 1.37, 95% CI 0.95–1.98) was similar to the summary estimate of several randomized trials in a Cochrane meta-analysis (OR 1.45, 95% CI 1.10–1.92) [15]. These data are therefore consistent with previous evidence in that no clinical benefit is conferred by routine insertion. To the authors' best knowledge, only one other study has explored the timing of selective NGT insertion. This suggested that reactive insertion (insertion after vomiting) may be associated with an increased risk of pneumonia due to greater exposure to high-volume vomiting [17].

The limitations of this study are recognized. Firstly, selection bias may have existed in the patient groups receiving prophylactic and reactive NGT insertion. For example, patients deemed to be of higher perioperative risk of pulmonary complications may have been more likely to receive early 'prophylactic' insertion. Whist the multivariable analysis adjusted for clinically relevant confounders, it is possible that unmeasured factors exist which have disguised the true effect of timing of NGT insertion on the rates of pneumonia. Secondly, all time-to-event data were recorded to the nearest day. Where a NGT was inserted on the same day that a patient vomited it was not possible to ascertain the order in which these events occurred and all such cases were considered in the reactive NGT group. This approach is considered reasonable, since the occurrence of vomiting during or

soon after NGT insertion implies a failure of treatment, thus exposing patients to the same risk factors. Future work should draw on these data and explore the association with greater precision. A third limitation relates to the observed difference in Clavien–Dindo grades between groups. It was hypothesized that this may be due to differences in postoperative care pathways (such as admission to critical care) which may indicate a notable selection bias. On the other hand, since the two groups were similar with respect to demographic and intra-operative factors, it is proposed that the impact of any such bias on the primary analysis is small. A fourth limitation is that no formal definition of postoperative pneumonia was prespecified in the study protocol according to accepted reference standards [18]. However, as pneumonia is primarily a radiological diagnosis, the impact of this is expected to be minimal and unlikely to cause differential misclassification between study groups. A final limitation of this study is its statistical power. Based on small sample sizes in the reactive and prophylactic NGT groups, along with an overall rate of pneumonia for this cohort of 10.8%, a post-hoc power calculation returned a minimal detectable odds ratio of approximately 2.25, at 80% power and 5% alpha. As such, it would be possible for a clinically relevant difference between groups to exist which may not be statistically significant.

The present data were unable to define an optimal timing for selective insertion of a NGT after surgery. Contrary to current beliefs, these data suggest that prophylactic insertion prior to episodes of vomiting may be ineffective at mitigating the risk of pneumonia. These results alone should not deter the use of NGTs, since they can have a useful role in appropriately selected patients. Instead, the results should encourage further investigation to explore how stratification of patients at high risk of ileus (and decisions to insert a NGT) can be improved.

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Conflicts of interest

The corresponding author has completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declares: no support from any organization for the submitted work, no financial relationships with any organizations that might have an interest in the submitted work in the previous 3 years and no other relationships or activities that could appear to have influenced the submitted work.

Author contributions

All collaborators participated in data collection. Local and national leads participated in study management with oversight from the Steering Committee. The Writing Group drafted and finalised the manuscript and all individuals agreed for its submission. The corresponding author attests that all listed collaborators meet required criteria and that no others have been omitted. JH is the statistical guarantor and SJC is the overall guarantor.

Data Availability Statement

Proposals for further analyses should be forwarded to the corresponding author. These shall be reviewed by the study team, including a trained statistician. If considered to be feasible, the proposer will be invited to work with the study team to facilitate the analysis and subsequent manuscript(s). All manuscripts arising from EuroSurg data must be authored according to the corporate authorship model of 'EuroSurg Collaborative'.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Demographics by routine nasogastric tube insertion in the intention-to-treat analysis.

Table S2. Intra- and postoperative factors by routine nasogastric tube insertion in the intention-to-treat analysis.

Table S3. Multivariable analyses for factors associated with postoperative pneumonia in the intention-to-treat analysis of routine nasogastric tube (NGT) versus no routine NGT.

Appendix S1. EuroSurg Collaborative members.