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ORIGINAL ARTICLE

Predictive Factors of Atelectasis Following Endoscopic Resection

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Abstract

Background and Aim Atelectasis is one of the pulmonary complications associated with anesthesia. Little is known about atelectasis following endoscopic procedures under deep sedation. This study evaluated the frequency, risk factors, and clinical course of atelectasis after endoscopic resection.

Methods A total of 349 patients who underwent endoscopic resection of the upper gastrointestinal tract at a single academic tertiary referral center from March 2010 to October 2013 were enrolled. Baseline characteristics and clinical data were retrospectively reviewed from medical records. To identify atelectasis, we compared the chest radiography taken before and after the endoscopic procedure.

Results Among the 349 patients, 68 (19.5 %) had newly developed atelectasis following endoscopic resection. In univariate logistic regression analysis, atelectasis correlated significantly with high body mass index, smoking, diabetes mellitus, procedure duration, size of lesion, and total amount of propofol. In multiple logistic regression analysis, body mass index, procedure duration, and total propofol amount were risk factors for atelectasis following endoscopic procedures. Of the 68 patients with atelectasis, nine patients developed fever, and six patients displayed pneumonic infiltration. The others had no symptoms related to atelectasis.

Conclusions The incidence of radiographic atelectasis following endoscopic resection was nearly 20 %. Obesity, procedural time, and amount of propofol were the significant risk factors for atelectasis following endoscopic procedure. Most cases of the atelectasis resolved spontaneously with no sequelae.

Keywords Atelectasis · Endoscopic resection · Sedation

Introduction

Endoscopic resection with strip biopsy was first applied in 1984 to a patient with early gastric cancer [1]. Since then, the procedure has evolved in terms of devices and techniques [1]. Nowadays, endoscopic en bloc resection of gastric neoplastic lesion is a preferred treatment option [2]. Endoscopic resection is relatively less invasive and inexpensive, and has more rapid post-procedural recovery and better clinical outcome at long-term follow-up than surgery [2, 3].

Despite these advantages, endoscopic resection has risks [4]. Common complications of endoscopic resection are bleeding, perforation, and stenosis [4]. Because an endoscopic resection often requires a longer procedural time and sedation duration than a simple diagnostic endoscopy, it is possible that sedation-related cardiopulmonary complications following endoscopic resection occur more frequently [5, 6].

Atelectasis, the reversible collapse of the alveoli, is one of the most common post-operative pulmonary complications [7]. Atelectasis can cause various symptoms like fever, tachypnea, dyspnea, hypoxemia, cough, and increased

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sputum production. Although it most commonly presents a benign course with spontaneous resolution within 48 h, it often causes unnecessary discomfort to patients [7–9]. If atelectasis persists longer, it contributes to significant morbidity and additional health care costs [7–10]. Atelectasis can occur following non-surgical procedure under deep sedation, such as endoscopic resection. However, previous studies have focused on perioperative atelectasis performed under general anesthesia [11–14]. Few focused on endoscopic procedures performed under deep sedation.

The objectives of this study are to evaluate the frequency, risk factors, and clinical course of atelectasis following endoscopic resection under deep sedation.

Patients and Methods

Patients and Study Design

This retrospective study included all patients who underwent endoscopic resection by one endoscopist at our institution from March 2010 through October 2013. All patients provided written informed consent prior to the procedure. This study was approved by the Institutional Review Board of Korea University School of Medicine, which confirmed that the study was in accordance with the ethical guidelines of the Helsinki Declaration (AS 12114). Baseline characteristics and procedure-related factors of suspicious causes of atelectasis, such as the location and size of the lesion, duration of procedure, and amount of sedative agents, were taken from their medical records. Patients who had received endoscopic resection under general anesthesia with endotracheal intubation were excluded. Patients who developed perforation were also excluded because pneumoperitoneum after perforation causes atelectasis in itself.

Endoscopic Procedure

Endoscopic resection was performed on upper gastrointestinal neoplastic lesions diagnosed by endoscopic evaluation. All patients were positioned in the left lateral decubitus position during the procedure. Air was insufflated using the ordinary air inlet system of the endoscope rack. Endoscopic resection was performed with a standard single-accessory channel endoscope (GIF-H260; Olympus). After the tumor outline was confirmed by chromoscopy, marking dots were placed along the outer tumor margin using a model MTW-020121 needle knife (MTW Company, Inc.) or model FM-EKOOO3-2 ClearCut knife (Finemedix Co., Ltd.). A model KD-611L insulated-tip (IT) knife (Olympus) was used for circumferential mucosal incision. The lesion was resected by submucosal dissection or snaring after pre-cutting as decided by the endoscopist. The decision was based on the size and shape of the lesion, and the histopathologic finding of pre-procedural biopsy. Subepithelial tumor was enucleated by cutting the mucosa and dissecting fibrous tissue around the exposed tumor using an IT-knife.

Sedation

We targeted deep sedation during the endoscopic procedure. Deep sedation was the loss of consciousness with retention of spontaneous respiration and protective reflexes. Intravenous sedative agents were administrated under gastroenterologist supervision. Induction of sedation was done initially by using a combination of midazolam of 2–4 mg and propofol of 0.5–1 mg per weight (kg). Sedative substances (midazolam 1 mg or propofol 20 mg) were administered additionally and intermittently to maintain sedation. When complications, such as hypoxemia or the transition from deep sedation to general anesthesia occurred, the administered agents were stopped and stimulated the patient to awake.

Oxygen supply was maintained at a constant level of 2 L/min via a nasal prong during the procedure. Pulse rate, blood pressure, and saturation pulse oximetry (SpO_2) were monitored. When a hypoxic event (SpO_2 below 90 %) occurred, the oxygen supply was raised temporarily to 6 L/min until SpO_2 returned to over 95 %. After the patient's oxygen saturation became stable, the oxygen supply was readjusted back to a constant level of 2 L/min. Post-endoscopic procedure surveillance continued in the staffed recovery room until the patient completely recovered consciousness. Pulse oximetry monitoring continued to check the spontaneous respiration, and patients were kept in the supine position during recovery. To detect whether perforation had developed or not, chest radiography was done after patients had fully regained consciousness. After chest radiography, patients were moved to the general ward and monitored for at least 48 h to detect possible delayed complications.

Diagnosis of Atelectasis

All patients received pre-procedure chest radiography and routine laboratory tests to identify conditions that could increase peri-procedural morbidity and mortality. Post-procedure atelectasis was diagnosed by radiological examination after endoscopic resection. In order to identify atelectasis, the chest radiographs taken before and after endoscopic resection were reviewed by two radiologists who were blinded to the endoscopic procedure. The diagnostic criterion of atelectasis was defined as direct or indirect signs of atelectasis observed on chest radiography

regardless of clinical symptoms (Table 1; Fig. 1) [8, p. 159]. When atelectasis already existed before the endoscopic procedure, endoscopy-related atelectasis was defined only in the cases of aggravation after the procedure or new development in other segments. Apart from atelectasis, all pre-existing radiographic abnormality and newly developed abnormalities, such as emphysema, interstitial lung disease, bronchiectasis, tuberculosis-destroyed lung, pre-existing atelectasis, pulmonary edema, effusion, and pneumonic infiltration, were also recorded. Aspiration pneumonia was referred specifically to the development of radiographically evident infiltration and centrilobular nodules, which are typical findings to discriminate from atelectasis. Post-review, the two sets of descriptions (one from each radiologist) were compared. In case of a discrepancy, the final diagnosis was determined by clinicians based on clinically relevant information, including dyspnea, sputum, fever with chilling, and aspiration history during the procedure. Fever was defined as a temperature above 37.8 °C (100.0 °F) at the tympanic membrane.

Statistical Analyses

Data of baseline characteristics, procedure-related factors, and radiography of enrolled patients were stored consecutively in a database. An independent samples *t* test was used to analyze differences between two groups (atelectasis vs non-atelectasis). Chi-square test was used for comparison of categorical variables between the two groups. Univariate and multivariate logistic regression analyses were used to assess the effect of independent variables adjusted for effects of all other variables. The differences were considered to be significant at $p < 0.05$. We compared radiologists' judgments about confirmation of the atelectasis, calculating the kappa statistic to correct for chance agreement. All analyses were performed using SPSS Statistics version 20 (IBM).

Table 1 Radiographic signs of atelectasis

Direct signs of atelectasis
A. Crowding of pulmonary vessels
B. Crowded air bronchogram
C. Displacement of interlobar fissure[a]
Indirect signs of atelectasis
A. Pulmonary opacification
B. Elevation of the ipsilateral diaphragm
C. Displacement of the trachea, heart, and mediastinum[a]
D. Displacement of the hilum[a]
E. Compensatory hyperexpansion of the surrounding lung
F. Approximation of the ipsilateral ribs
G. Shifting granuloma
H. Juxtaphrenic peak[b]

[a] Toward the side of collapse

[b] The peaked or tented appearance of a hemidiaphragm retracted into an inferior accessory fissure or major fissure or inferior pulmonary ligament, in the setting of upper and/or middle lobar collapse

Results

During the study period, 356 patients received endoscopic resection. Among them, three patients received endoscopic resection under general anesthesia and four patients developed immediate perforation after the procedure. These patients were excluded from the analysis. In total, 349 patients were included in this study. Table 2 shows the comparison of clinical characteristics of the two groups according to the presence of atelectasis.

In 309 patients, one neoplastic lesion was found and resected in each patient. The other 40 patients had two synchronous lesions to undergo endoscopic resection in each. Among patients who received endoscopic resection, 192 received endoscopic submucosal dissection and 120 received endoscopic mucosal resection by snaring after pre-cutting with an IT knife. The other 37 patients received enucleation for subepithelial lesion by dissection of the fibrous tissue around the tumor using an IT knife. In the 349 patients, delayed perforation or massive hemorrhage requiring surgical treatment was not developed, and local recurrence and metastasis did not occur in any patient during the median 42-month (range 25–69 months) follow-up.

Radiographic atelectasis developed in 68 (19.5 %) patients. The initial radiologist confirmed that 68 patients showed post-procedural atelectasis. Meanwhile, the reviewer diagnosed atelectasis in 72 patients. The two observers agreed perfectly with atelectasis in 57 patients among those patients. Agreement about radiologic atelectasis was substantial agreement (kappa = 0.68) between two radiologists. While 60 patients developed atelectasis in the left lung alone (58 in the left lower lobe and two in the left upper lobe), four patients developed atelectasis in the right lung alone (two in the right middle lobe and two in the right lower lobe). Four patients developed atelectasis in both lungs: one patient had right middle, lower lobe and left lower lobe atelectasis, and three patients had atelectasis on both lower lobes.

Risk Factors for Atelectasis

Univariate logistic regression analysis was performed to assess the association between the pre-specified predictor variables and atelectasis. Patient-related variables of body mass index (BMI), smoking, and diabetes mellitus, were

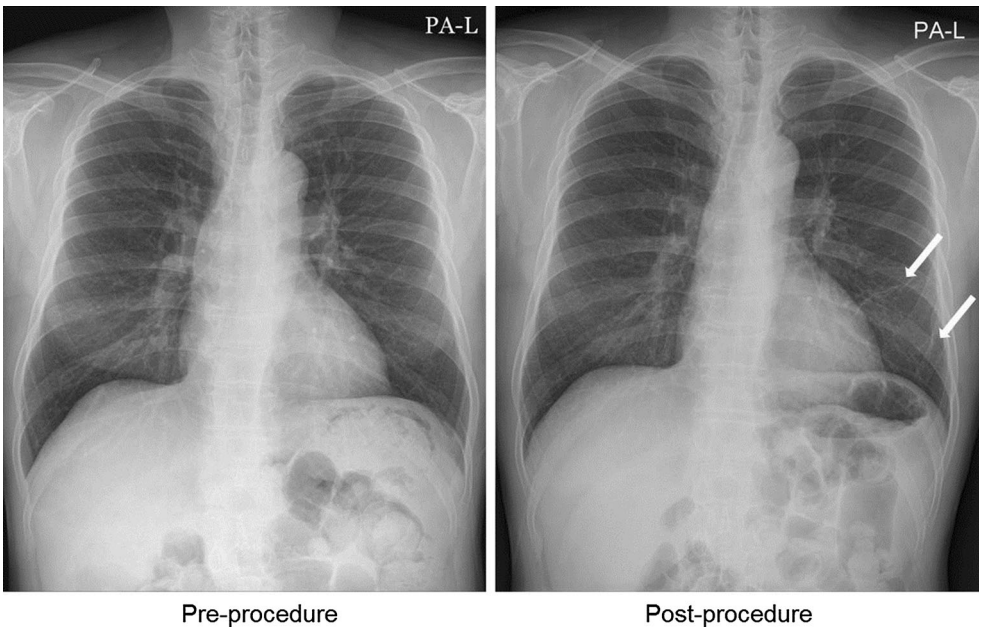

Fig. 1 Posteroanterior view of chest radiographs obtained on pre- and post-procedure. The *right image* showed transversely and longitudinally linear dense opacities (*white arrow*) of *left lower* lobe consistent with post-procedural atelectasis

significantly associated with the development of atelectasis. Age, gender, and other comorbid conditions were not associated with the development of atelectasis. Concerning procedure-related variables, lesion location, initial dose of sedative agents, and total amount of midazolam did not reach statistical significance, but procedure duration, lesion size, and total amount of propofol were associated with a higher frequency of atelectasis (Table 3). In the multivariate logistic regression analysis for patient- and procedure-related variables, BMI (kg/m^2), procedure duration, and total amount of propofol were significantly correlated with atelectasis (Table 4).

Clinical Course of Atelectasis

All patients with atelectasis did not need prolonged hospitalization or respiratory interventions, such as bronchoscopy or positive pressure ventilation. Fever developing within 24 h after endoscopic resection occurred in 20 of 349 patients. Of the 68 subjects with atelectasis, nine developed fever, whereas 11 of 281 patients with non-atelectasis developed a fever. The frequency of fever development was significantly higher in patients with atelectasis (13.2 vs 3.9 %; $p = 0.007$; Fig. 2a). In all 20 patients, fever was spontaneously resolved within 48 h independent of antibiotics use. Antibiotic was only prescribed to two patients with both fever and radiographical pneumonic infiltration. However, the fever in the two patients was resolved by a two-day regimen of antibiotics after the endoscopic procedure. No additional study was performed to identify the pathogen and the two patients were discharged without further antibiotic treatment. Eight patients were diagnosed as pneumonic infiltration upon post-procedure chest radiography after endoscopic resection. Six of the eight patients had atelectasis. The frequency of pneumonic infiltration was significantly higher in patients with atelectasis (8.7 vs 0.7 %; $p = 0.001$; Fig. 2b). All patients with pneumonic infiltration had asymptomatic or benign course including temporary fever, cough, and sputum, which resolved within 48 h.

Discussion

Atelectasis is one of the most common post-operative pulmonary complications [15]. The prevalence of atelectasis in patients who undergo surgery under intravenous or inhaled anesthesia has been estimated as 19–90 %. It can develop both during spontaneous breathing and after muscle paralysis [16]. The frequency of atelectasis after endoscopic resection under intravenous deep sedation is unknown. The risk factors of post-operative atelectasis are well known and include obesity, impact time, high oxygen supply, low tidal volume, and type of surgery [7, 14, 17]. However, the risk factors of atelectasis following endoscopic resection have not been determined. Presently, the incidence of atelectasis following endoscopic procedure is nearly 20 % with some risk factors identified.

Atelectasis is considered to result from the combined effects of three mechanisms. One of the mechanisms is compression, which is defined as atelectasis induced by increasing intra-abdominal pressure that can collapse the alveoli [13, 16, 17]. When the air through the endoscopic channel insufflates the stomach during the endoscopic

Table 2 Baseline characteristics of enrolled patients

Characteristic	Total ($n = 349$)	Atelectasis ($n = 68$)	Non-atelectasis ($n = 281$)	p value
Gender, no. (%)				0.344
Male	224 (64.2)	47 (69.1)	177 (63.0)	
Female	125 (35.8)	21 (30.9)	104 (37.0)	
Mean age (years) [±SD]	60.0 [±12.8]	60.2 [±12.9]	59.9 [±12.8]	0.882
Mean BMI (kg/m^2) [±SD]	24.3 [±3.2]	25.2 [±3.1]	24.1 [±3.2]	0.014
Smoking history, no. (%)				0.049
Smoker	133 (38.1)	33 (48.5)	100 (35.6)	
Non-smoker	216 (61.9)	35 (51.5)	181 (64.4)	
Presence of comorbid conditions (%)				
Diabetes mellitus	56 (16.0)	17 (25.0)	39 (13.9)	0.025
Hypertension	127 (36.4)	29 (42.6)	98 (34.9)	0.232
Pulmonary disease[a]	49 (14.0)	7 (10.3)	42 (14.9)	0.322
COPD or emphysema	19 (5.4)	1 (1.5)	18 (6.4)	0.14
Cardiovascular disease	17 (4.9)	6 (8.8)	11 (3.9)	0.113
CNS disease	17 (4.9)	4 (5.9)	13 (4.6)	0.753
History of gastrectomy	10 (2.9)	2 (2.9)	8 (2.8)	1
Location, no. (%)				0.505
Esophagus	9 (2.6)	2 (2.9)	7 (2.5)	
Lower stomach	206 (59.0)	36 (52.9)	170 (60.5)	
Middle stomach	88 (25.2)	17 (25.0)	71 (25.3)	
Upper stomach	41 (11.7)	11 (16.2)	30 (10.7)	
Duodenum	5 (1.4)	2 (2.9)	3 (1.1)	
Starting time of procedure, no. (%)				0.639
Before 12:00	181 (51.9)	37 (54.4)	144 (51.2)	
After 12:00	168 (48.1)	31 (45.6)	137 (48.8)	
Median procedure duration, min [range]	46.7 [10–210]	57.8 [11–165]	44.0 [10–210]	0.005
Mean size, cm [±SD]	3.04 [±1.29]	3.42 [±1.41]	2.95 [±1.25]	0.007
Mean dose of sedative agent, mg [±SD]				
Initial dose of midazolam	3.4 [±1.4]	3.6 [±1.4]	3.3 [±1.5]	0.176
Initial dose of propofol	50.0 [±26.3]	46.3 [±25.6]	51.0 [±26.4]	0.193
Total amount of midazolam	6.7 [±3.9]	6.7 [±3.5]	5.8 [±3.9]	0.001
Total amount of propofol	162.3 [±89.0]	194.0 [±107.5]	154.6 [±82.3]	0.001

BMI body mass index, *COPD* chronic obstructive pulmonary disease, *CNS* central nervous system, *SD* standard deviation

[a] Includes pre-existing incidental findings on chest radiography, such as emphysema, interstitial lung disease, bronchiectasis, tuberculosis-destroyed lung, pre-existing atelectasis, pulmonary edema, and effusion

resection, intra-intestinal pressure followed by intra-peritoneal pressure is increased, which affects the thoracic cavity [13, 16, 17]. In our study, increased BMI was also a significant risk factor of atelectasis. This may be explained by higher intra-abdominal pressure than non-obese patients [18]. Another mechanism is gas resorption. Lung zones with low ventilation/perfusion [V_A/Q] ratio have low partial pressure of alveolar oxygen (PaO_2) [16, 17]. In this condition, higher FiO_2 increases the net flow of oxygen from alveolar gas to capillary, and the excessive flow of alveolar gas leads to a collapse of the lung [17]. The left lung compressed in the left decubitus position has low ventilation and high FiO_2 with oxygen consistent 2 L/min supply via a nasal prong. These factors result in atelectasis predominantly in the left lung. Gas resorption is dominant in the left lung because ventilation/perfusion [V_A/Q] ratio is lower in the dependent portion of the lung and constant high FiO_2 shunts excessively alveolar gas to capillary [13, 16, 17]. Presently, most cases of atelectasis involved the left lung. The other mechanism is surfactant impairment by sedative agents. Surfactant prevents the collapse of the alveoli by lowering surface tension and contributing to

Table 3 Univariate logistic regression analysis for factors associated with atelectasis

Factor	Odds ratio	95 % Confidence interval	*p* value
Patient-related factors			
Gender, male/female	1.315	0.745–2.322	0.399
Age	1.002	0.981–1.023	0.882
BMI	1.107	1.020–1.202	0.015
Smoking history, yes/no	1.707	1.000–2.913	0.034
Presence of comorbid conditions			
Diabetes mellitus	2.068	1.086–3.941	0.041
Hypertension	1.389	0.810–2.382	0.262
Pulmonary disease[a]	0.653	0.280–1.525	0.436
COPD or emphysema	0.218	0.029–1.663	0.14
Cardiovascular disease	2.375	0.846–6.669	0.113
CNS disease	1.288	0.407–4.083	0.753
History of gastrectomy	1.038	0.455–2.366	1
Procedure-related factors			
Location	0.667	0.550–0.081	0.527
Esophagus	0.741	0.148–3.716	0.716
Lower stomach	0.838	0.160–4.399	0.838
Middle stomach	1.283	0.231–7.143	0.776
Upper stomach	2.333	0.216–25.245	0.486
Duodenum			
Procedure duration	1.011	1.004–1.019	0.003
Size of lesion	1.306	1.071–1.593	0.008
Initial dose of midazolam	1.137	0.944–1.370	0.176
Initial dose of propofol	0.993	0.983–1.004	0.193
Total amount of midazolam	1.05	0.986–1.118	0.126
Total amount of propofol	1.005	1.002–1.007	0.001

BMI body mass index, *CI* confidence interval, *COPD* chronic obstructive pulmonary disease, *CNS* central nervous system

Table 4 Multivariate logistic regression analysis for factors associated with atelectasis

Factors	Adjusted odds ratio	95 % confidence interval	*p* value
BMI	1.109	1.013–1.214	0.026
Smoking history	1.587	0.901–2.794	0.110
Diabetes mellitus	1.741	0.874–3.466	0.115
Procedure duration	1.005	0.994–1.016	0.001
Size	1.011	0.985–1.037	0.420
Total amount of propofol	1.005	1.002–1.007	0.002

BMI body mass index, *CI* confidence interval

alveolar stabilization [16, 17]. Anaesthetic agents may depress the stabilizing function of surfactant [17].

These mechanisms are not sufficient to explain the atelectasis of right lung. Interestingly, in the eight cases with right lung atelectasis, more sedative agents usage was reported. Concerning the total propofol amount, about 30 mg more was injected than in patients with only left lung atelectasis (219 vs 191 mg). They also remained longer in the recovery room (51 vs 38 min). The patients were generally supine during recovery. These factors could affect the development of atelectasis in the dependent portion of right lung.

In 49 patients with pulmonary disease or with an abnormality on chest radiography before the procedure, the underlying pulmonary disease did not increase the frequency of atelectasis significantly. Atelectasis rarely occurred in chronic obstructive pulmonary disease (COPD) patients. This is considered to occur because chronic

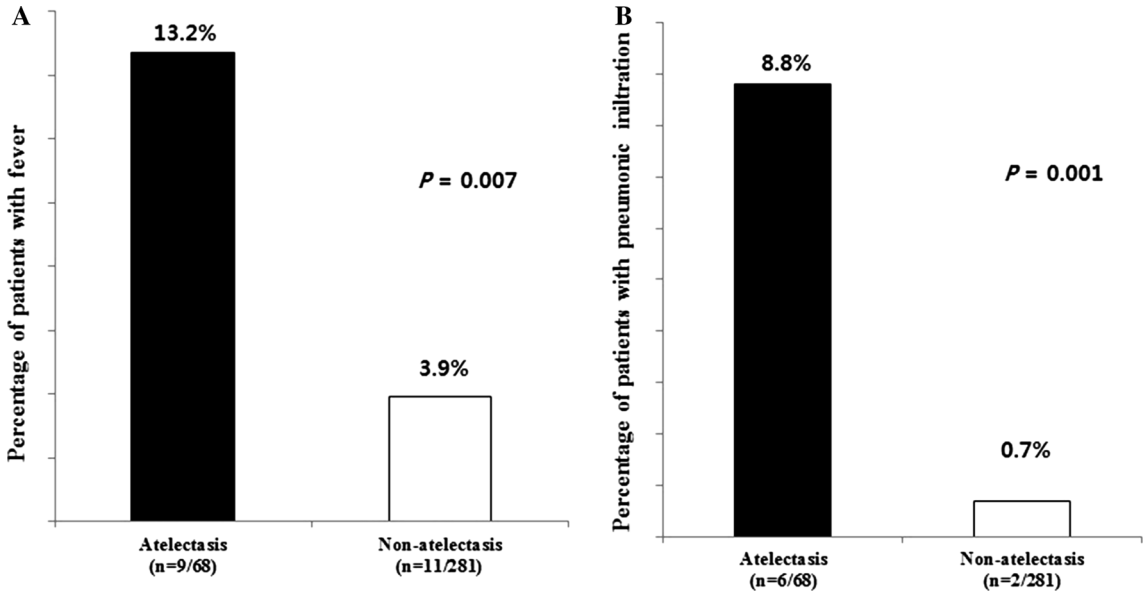

Fig. 2 Clinical course of atelectasis and non-atelectasis patients following endoscopic resection. **a** Percentage of patients with fever. **b** Percentage of patients showing pneumonic infiltration on chest radiography

hyperinflation and interaction with the chest wall of patients with COPD act as a counter effect against alveolar collapse [17, 19].

It has been assumed that if the procedure is performed in the morning, when the accumulated mucus is at its highest, the development of atelectasis will be affected. However, the relationship between the starting time of the procedure and atelectasis was not statistically significant.

In general, postoperative atelectasis can often be improved with positive-pressure maneuvers and adequate ventilation, postural change, physiotherapy, or respiratory muscle training [20, 21]. Presently, all the patients with atelectasis did not need further hospitalization or any intervention. However, some developed mild fever and radiological pneumonic infiltration complication. So, especially for patients at high risk for atelectasis, the aforementioned treatments are expected to be a preventive strategy and help in the early recovery from atelectasis following endoscopic procedures.

As an observational study, this study conducted a survey of patients admitted for endoscopic resection under deep sedation, and the subjects were restricted to patients who received endoscopic resection by a single endoscopist. Delayed adverse events and clinical outcomes after the procedure were obtained consistently through the regular follow up. In addition, all patients took chest radiographs before and after the procedure to check for pre-existing radiographic abnormalities and confirm post-procedure perforation. Chest radiographs were reviewed by two separate radiologists who were blinded to patient history and endoscopic procedure.

Our study has several limitations. First, there were not sufficient data about other possible confounding factors contributing to the development of atelectasis. A pulmonary function test was not performed before the procedure, so influences like tidal volume, forced expiratory volume in the first second (FEV1), and functional residual capacity (FRC) on developing atelectasis were not reflected in the results. Second, it is possible that patient's discomfort was underestimated. While fever was accurately checked during routine vital sign examinations after the procedure, other symptoms related to patient discomfort were not assessed regularly. Larger prospective controlled trials are warranted to clarify the relationship between atelectasis and endoscopic resection.

In conclusion, the frequency of radiographic atelectasis after endoscopic resection was nearly 20 %. Obesity, procedural time, and amount of propofol were the significant risk factors for atelectasis following endoscopic procedure. Most cases of the atelectasis resolved spontaneously with no sequelae.

Compliance with ethical standards

Conflict of interest None.

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