Aspiration pneumonia and anesthesia techniques in hip fracture surgery in elderly patients: A retrospective cohort study using administrative data

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Abstract

Purpose: Aspiration pneumonia is a critical issue. General anesthesia may suppress the airway’s protective reflex. However, aspiration pneumonia is also observed in patients who undergo hip fracture surgery under spinal anesthesia. The aim of this study was to investigate the relationship between anesthesia methods and aspiration pneumonia as well as the predictive factors of aspiration pneumonia in elderly patients undergoing hip fracture surgery. Methods: The medical records of 19,809 patients aged ≥60 years who underwent hip fracture surgery under general or spinal anesthesia were reviewed. After propensity score matching, the anesthesia methods affecting the occurrences of aspiration pneumonia and other complications were investigated via logistic regression and instrumental variable analyses. Predictive factors of aspiration pneumonia were also investigated in all subjects using a multivariable logistic regression analysis. Results: Among the 11,673 general anesthesia patients and 8136 spinal anesthesia patients, aspiration pneumonia occurred in 356 patients (1.8%). Post-propensity score matching the incidences of aspiration pneumonia with general and spinal anesthesia were 1.8% and 1.5%, respectively (p = 0.158); other pulmonary complications were 1.5% and 1.5%, respectively (p = 0.893); and the mortality rates were 1.4% and 1.2%, respectively (p = 0.219). The predictive factors of aspiration pneumonia were advanced age, male sex, lean body, cerebrovascular disease, dementia, and dependency for activities of daily living (eating). Conclusion: Spinal and general anesthesia showed similar incidences of aspiration pneumonia in elderly hip fracture surgery. Regardless of the anesthesia method, great care should be taken, especially in elderly patients with the identified predictive factors.

Keywords

aspiration pneumonia, elderly, general anesthesia, hip fracture surgery, spinal anesthesia

Introduction

Aspiration pneumonia occurs in approximately 1% of surgical patients,1 and perioperative aspiration pneumonia is associated with significantly high mortality.1–3 The frequency of aspiration pneumonia increases with age.4 Similarly, the frequency of osteoporotic fractures also increases with age. The number of hip fractures was about 1.6 million worldwide in 2000, and it is estimated to reach 4.5 million by 2050.5,6

General anesthetics and/or airway interventions inhibit laryngeal defensive reflexes.7,8 Since upper airway reflex sensitivity decreases with increasing age,9,10 general
anesthesia may increase the risk of aspiration pneumonia in elderly patients. However, current general anesthetics have a rapid elimination time.\textsuperscript{11–13} Since most patients undergo hip fracture surgery after an appropriate fasting period, aspiration of gastric contents during anesthesia induction is unlikely. Furthermore, Studer et al.\textsuperscript{3} reported that postoperative aspiration pneumonia occurs at 7 ± 10 days after surgery. It is still unclear whether general anesthesia is associated with postoperative aspiration pneumonia in elderly hip fracture surgery patients. Therefore, the aim of this study was to investigate whether anesthesia methods are related to the occurrence of aspiration pneumonia in elderly patients undergoing hip surgery. We also investigated the predictive factors of postoperative aspiration pneumonia.

\section*{Methods}

The study was approved by the ethical review boards of our hospital (2019-1; principal investigator, T.F.; date of approval, January 2019) and the National Hospital Organization (NHO). Following the Japanese ethical guidelines for human medical research, which are based on the Declaration of Helsinki, the study protocol was open to the general public via websites in order to obtain patient objections. To protect patient privacy, all personal identification data were encrypted in a security room of the NHO data bank. The requirement for written informed consent was waived by the ethical review boards.

\section*{Data sources}

A retrospective cohort study was conducted using data from an administrative database. The research period was from 1 April 2010, to 31 March 2019. Data from 81 NHO hospitals were used. The data were obtained from the Japanese Diagnosis Procedure Combination (DPC) administrative claims database. The DPC database is a diagnosis-dominant, case-mix system administered by Japan’s Ministry of Health, Labour and Welfare, and it is linked with a lump-sum payment system. The data include the primary diagnosis, the diagnosis on admission, the most and second-most resource-consuming diagnoses, 10 comorbid diagnoses on admission, and 10 complications during hospitalization. Hospital scale data were obtained from the NHO’s resident recruitment guidebooks and each hospital’s website.

\section*{Selection of patients and variables}

The inclusion criteria were as follows: (1) patients who underwent surgery during the research period for a hip fracture (transcervical, intertrochanteric, or subtrochanteric femoral fracture) within 4 days of hospitalization, including the day of hospitalization; (2) patients who underwent total arthroplasty, hemiarthroplasty, or another typical hip fracture procedure (plate/screw or intramedullary implant); and (3) patients who underwent either general anesthesia or spinal anesthesia. The general anesthesia group included patients who received a combination of general anesthesia and an epidural block. Patients who received unknown anesthesia, mixed spinal and general anesthesia, or other anesthesia types were excluded. We also excluded younger patients (<60 years old).

The data from the DPC database included age, sex, height, weight, smoking status, fracture type, surgery date, surgical procedure, drug treatment (sedatives), comorbidities on admission, diseases occurring after admission, and functional status, which was based on the patient’s ability to perform tasks related to activities of daily living (ADLs) before admission. Body mass index (BMI) was calculated from height and weight. A BMI between 25 kg/m\textsuperscript{2} and 29.9 kg/m\textsuperscript{2} is considered overweight, while a BMI ≥30 kg/m\textsuperscript{2} is considered obese.\textsuperscript{14} However, many Japanese people are relatively thin. In this study, only 1% of subjects had a BMI ≥30 kg/m\textsuperscript{2}. Therefore, BMI was divided into three groups: <18.5 kg/m\textsuperscript{2}, 18.5–24.9 kg/m\textsuperscript{2}, and ≥25 kg/m\textsuperscript{2}. All diagnoses were defined using the codes of the International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10). Surgical procedures were defined using Japanese procedure codes. Surgical cost, including technical fees and material costs, was selected for compensate classification of the surgical procedures. Functional status includes the following parameters: (1) eating, (2) transferring, (3) grooming, (4) toileting, (5) bathing, (6) walking on a flat floor, (7) using stairs, (8) dressing, (9) defecating, and (10) micturating.\textsuperscript{15} Five parameters (eating, grooming, toileting, bathing, and walking) were selected from these 10 ADLs as indicators of physical weakness.\textsuperscript{16} The age-adjusted Charlson Comorbidity Index (CCI) score was calculated for each patient based on Quan et al.’s coding algorithms.\textsuperscript{17,18}

The first outcome variable was the occurrence of aspiration pneumonia, identified as J69.0 in the ICD-10. The definition of J69.0 is “pneumonia due to inhalation of food and vomit.” This definition does not take into account the severity of aspiration pneumonia. The second outcome variables were the occurrences of pneumonia (J13–18), bronchitis (J20–22), atelectasis (J98.1), pneumothorax (J93), pulmonary edema (J81), pulmonary embolism (I26), and death in the hospital. We defined these variables using the ICD-10 code recordings of the diagnosis categories of the complications during hospitalization.

\section*{Propensity score matching}

A propensity score-matched analysis without replacement was used to reduce the selection bias and potential baseline differences between the general and spinal anesthesia
groups. Scores were calculated using a binary logistic regression analysis, with anesthesia type as the dependent variable and 26 preoperative factors as the predictor variables. The independent variables included age, sex, BMI, age-adjusted CCI score, smoking status, delirium, fracture type, surgery type, surgical cost, days from hospitalization to surgery, sedative administration, hospital scale (number of beds), calendar date (year), pre-hospitalization ADL parameters (eating, grooming, toileting, bathing, and walking), and some comorbidities that are closely related to the choice of anesthesia method: atrial fibrillation/atrial flutter (I48), cerebrovascular diseases (I60–69), coagulopathy (D65–69), mental disorders (F00–99), neurologic diseases (G00–99), respiratory diseases (J00–99), thrombophlebitis (I80), and vertebral diseases (M40–54). The C-statistic was used to evaluate the discriminatory ability of the model. The caliper was set at 0.2 times the standard deviation of the estimated propensity score. Standardized differences were used to compare the characteristics between the two groups before and after matching.

**Statistical analysis**

The preoperative variables were compared between the general and spinal anesthesia groups using the chi-square test. ADL independence was compared between patients with and without aspiration pneumonia using the chi-square test. The occurrences of aspiration pneumonia, other pulmonary complications, and mortality were assessed via logistic regression analysis after propensity score matching. Odds ratios and 95% confidence intervals were then estimated.

Hidden biases caused by unmeasured confounders, such as the hospital’s characteristics, may not have been removed with the propensity score-matched analysis. Therefore, we performed an instrumental analysis and a sensitivity analysis after propensity score matching. Based on the proportions of general anesthesia and spinal anesthesia performed at the NHO hospitals between 1 April 2019, and 31 March 2020, we classified each hospital into one of two groups—one with a high proportion of general anesthesia and the other with a low proportion of general anesthesia—and used this classification as an instrumental variable. A two-stage residual inclusion model was used to estimate the effect of each anesthesia method on the outcomes.

To investigate the predictive factors of aspiration pneumonia, a multivariable logistic regression analysis was performed between aspiration pneumonia-positive and -negative patients. In addition to anesthesia methods, the following factors were selected for the model: age, sex, BMI, cerebrovascular disease, Parkinson disease/syndrome, dementia, and initial ADL ability (eating). These variables were previously suggested to have an effect on postoperative pulmonary complications.

**Results**

Figure 1 shows the patient selection process. In the DPC database, a total of 39,800 patients who underwent hip fracture surgery during the observation period (1 April 2010 to 31 March 2019) were identified. Among the identified patients, a total of 19,991 were excluded because other anesthesia methods were used, there were multiple surgeries, the patient was under 60 years of age, or surgery was delayed by more than 4 days. There were 19,809 patients who met the inclusion criteria (11,673 general anesthesia patients and 8136 spinal anesthesia patients). Propensity score matching yielded 7519 pairs, and the C-statistic for the logistic regression was 0.651 (95% confidence interval: 0.643–0.658).

For the 19,809 patients, the morbidity of aspiration pneumonia was 1.8% (356 patients). For patients in their 60s, 70s, 80s, and ≥90s, the morbidities of aspiration pneumonia were 0.7%, 1.3%, 1.8%, and 2.4%, respectively. For aspiration pneumonia-positive and -negative patients, the mortalities were 19.1% and 1.0%, respectively (p < 0.001).

Table 1 shows the baseline characteristic data of the general and spinal anesthesia groups. Before propensity score matching, the variables of age, sex, BMI, age-adjusted CCI score, fracture type, surgery type, surgical cost, surgery timing, frequency of sedation, frequency of delirium, hospital scale, year, ADLs before hospital admission, and some comorbidities were unbalanced between the two
|                          | Before propensity score matching | After propensity score matching |
|--------------------------|----------------------------------|--------------------------------|
|                          | General | Spinal | Standardized difference | General | Spinal | Standardized difference |
| n                        | 11,673  | 8136   |                         | 7519    | 7519   |                         |
| Age                      |         |        |                         |         |        |                         |
| 65–79                    | 3178 (27.2%) | 2054 (25.2%) | 0.045 | 1931 (25.7%) | 1916 (25.5%) | 0.005 |
| 80–89                    | 5678 (48.6%) | 3842 (47.2%) | 0.028 | 3619 (48.1%) | 3594 (47.8%) | 0.006 |
| 90+                      | 2817 (24.1%) | 2240 (27.5%) | 0.078 | 1969 (26.2%) | 2009 (26.7%) | 0.011 |
| Sex                      |         |        |                         |         |        |                         |
| Male                     | 2531 (21.7%) | 1597 (19.6%) | 0.052 | 1496 (19.9%) | 1488 (19.8%) | 0.003 |
| Female                   | 9142 (78.3%) | 6539 (80.4%) | 0.023 | 6031 (80.2%) | 6015 (79.8%) | 0.006 |
| Body mass index          |         |        |                         |         |        |                         |
| <18.5                    | 2976 (25.5%) | 2230 (27.4%) | 0.043 | 2071 (27.5%) | 2034 (27.1%) | 0.009 |
| 18.5–24.9                | 6324 (54.2%) | 4029 (49.5%) | 0.094 | 3808 (50.6%) | 3824 (50.9%) | 0.006 |
| 25+                      | 1083 (9.3%) | 681 (8.4%) | 0.032 | 642 (8.5%) | 636 (8.5%) | 0 |
| Unknown                  | 1290 (11.1%) | 1196 (14.7%) | 0.108 | 998 (13.3%) | 1025 (13.6%) | 0.009 |
| Age-adjusted Charlson co-morbidity index |         |        |                         |         |        |                         |
| 2.3                      | 1798 (15.4%) | 1265 (15.5%) | 0.003 | 1180 (15.7%) | 1165 (15.5%) | 0.006 |
| 4.5                      | 7662 (65.6%) | 5707 (70.1%) | 0.096 | 5201 (69.2%) | 5229 (69.5%) | 0.007 |
| 6+                       | 2213 (19.0%) | 1164 (14.3%) | 0.126 | 1138 (15.1%) | 1125 (15.0%) | 0.003 |
| Smoking                  |         |        |                         |         |        |                         |
| Smoker                   | 1012 (8.7%) | 702 (8.6%) | 0.004 | 652 (8.7%) | 655 (8.7%) | 0 |
| Non-smoker               | 9328 (79.9%) | 6442 (79.2%) | 0.017 | 5946 (79.1%) | 5964 (79.3%) | 0.005 |
| Unknown                  | 1333 (11.4%) | 992 (12.2%) | 0.025 | 921 (12.2%) | 900 (12.0%) | 0.006 |
| Delirium                 |         |        |                         |         |        |                         |
| -                        | 11,539 (98.9%) | 8067 (99.2%) | 0.031 | 7449 (99.1%) | 7453 (99.1%) | 0 |
| +                        | 134 (1.1%) | 69 (0.8%) | 0.031 | 10 (0.9%) | 66 (0.9%) | 0 |
| Fracture type            |         |        |                         |         |        |                         |
| Transcervical            | 5551 (47.6%) | 3655 (44.9%) | 0.054 | 3357 (44.6%) | 3355 (44.6%) | 0 |
| Intertrochanteric        | 5810 (49.8%) | 4284 (52.7%) | 0.058 | 3973 (52.8%) | 3977 (52.9%) | 0.002 |
| Subtrochanteric          | 312 (2.7%) | 197 (2.4%) | 0.019 | 189 (2.5%) | 187 (2.5%) | 0 |
| Surgery type             |         |        |                         |         |        |                         |
| Arthroplasty             | 3999 (34.3%) | 2263 (27.8%) | 0.141 | 2205 (29.3%) | 2182 (29.0%) | 0.007 |
| Other                    | 7674 (65.7%) | 5873 (72.2%) | 0.141 | 5314 (70.7%) | 5337 (71.0%) | 0.007 |

(continued)
|                     | Before propensity score matching |                      | After propensity score matching |                      |
|---------------------|---------------------------------|----------------------|---------------------------------|----------------------|
|                     | General | Spinal | Standardized difference | General | Spinal | Standardized difference |
| **Surgical cost (US$)** |         |        |                        |         |        |                        |
| 10,000+             | 635 (5.4%) | 156 (1.9%) | 0.187                 | 177 (2.4%) | 156 (2.1%) | 0.02                 |
| 6,000–10,000        | 3525 (30.2%) | 2168 (26.6%) | 0.080                 | 2101 (27.9%) | 2084 (27.7%) | 0.004                |
| 2000–6000           | 6994 (59.9%) | 5624 (69.1%) | 0.193                 | 5059 (67.3%) | 5092 (67.7%) | 0.009                |
| <2000               | 519 (4.4%)  | 188 (2.3%)  | 0.117                 | 182 (2.4%)  | 187 (2.5%)  | 0.006                |
| **Timing of surgery** |         |        |                        |         |        |                        |
| 0 days              | 1822 (15.6%) | 951 (11.7%) | 0.114                 | 900 (12.0%) | 922 (12.3%) | 0.009                |
| 1 day               | 3893 (33.4%) | 2650 (32.6%) | 0.017                 | 2493 (33.2%) | 2489 (33.1%) | 0.002                |
| 2 days              | 3212 (27.5%) | 2381 (29.3%) | 0.040                 | 2192 (29.2%) | 2181 (29.0%) | 0.004                |
| 3 days              | 2746 (23.5%) | 2154 (26.5%) | 0.069                 | 1934 (25.7%) | 1927 (25.6%) | 0.002                |
| **Sedation**        |         |        |                        |         |        |                        |
| Pre and post        | 648 (5.6%)  | 766 (9.4%)  | 0.145                 | 570 (7.6%)  | 585 (7.8%)  | 0.008                |
| Pre or post         | 3287 (28.2%) | 2519 (31.0%) | 0.061                 | 2303 (30.6%) | 2321 (30.9%) | 0.007                |
| -                   | 7738 (66.3%) | 4851 (59.6%) | 0.139                 | 4646 (61.8%) | 4613 (61.4%) | 0.008                |
| **Hospital scale (bed#)** |         |        |                        |         |        |                        |
| 400+                | 8003 (68.6%) | 4935 (60.7%) | 0.166                 | 4746 (63.1%) | 4715 (62.7%) | 0.008                |
| <400                | 3670 (31.4%) | 3201 (39.3%) | 0.139                 | 2773 (36.9%) | 2804 (37.3%) | 0.008                |
| **Year**            |         |        |                        |         |        |                        |
| 2010 Apr–2013 Mar   | 2441 (20.9%) | 2112 (26.0%) | 0.121                 | 1772 (23.6%) | 1828 (24.3%) | 0.016                |
| 2013 Apr–2016 Mar   | 3744 (32.1%) | 2460 (30.2%) | 0.041                 | 2319 (30.8%) | 2316 (30.8%) | 0                   |
| 2016 Apr–2019 Mar   | 5488 (47.0%) | 3564 (43.8%) | 0.064                 | 3428 (45.6%) | 3375 (44.9%) | 0.014                |
| **Activity of daily living (eating) at hospital admission** |         |        |                        |         |        |                        |
| Total depend        | 4327 (37.1%) | 2429 (29.9%) | 0.096                 | 2387 (31.7%) | 2357 (31.3%) | 0.009                |
| Partial depend      | 4580 (39.2%) | 3380 (41.5%) | 0.047                 | 3113 (41.4%) | 3089 (41.1%) | 0.006                |
| Independent         | 2542 (21.8%) | 2110 (25.9%) | 0.153                 | 1836 (24.4%) | 1894 (25.2%) | 0.019                |
| Unknown             | 224 (1.9%)  | 217 (2.7%)  | 0.053                 | 183 (2.4%)  | 180 (2.4%)  | 0                   |
| **Activity of daily living (grooming) at hospital admission** |         |        |                        |         |        |                        |
| Dependent           | 9932 (85.1%) | 6705 (82.4%) | 0.073                 | 6248 (83.1%) | 6237 (82.9%) | 0.005                |
| Independent         | 1506 (12.9%) | 1249 (15.4%) | 0.072                 | 1099 (14.6%) | 1120 (14.9%) | 0.008                |
| Unknown             | 235 (2.0%)  | 182 (2.2%)  | 0.014                 | 172 (2.3%)  | 162 (2.2%)  | 0.007                |
| **Activity of daily living (toileting) at hospital admission** |         |        |                        |         |        |                        |
| Dependent           | 10,462 (89.6%) | 7166 (88.1%) | 0.048                 | 6655 (88.5%) | 6650 (88.4%) | 0.003                |
| Independent         | 926 (7.9%)  | 803 (9.9%)  | 0.070                 | 697 (9.3%)  | 717 (9.5%)  | 0.007                |
| Unknown             | 285 (2.4%)  | 167 (2.1%)  | 0.020                 | 167 (2.2%)  | 152 (2.0%)  | 0.014                |
| Activity of daily living (bathing) at hospital admission | Before propensity score matching | After propensity score matching | Standardized difference | Before propensity score matching | After propensity score matching | Standardized difference |
|--------------------------------------------------------|-------------------------------|-------------------------------|----------------------|-------------------------------|-------------------------------|----------------------|
| Dependent                                              | 9632 (82.5%)                  | 6702 (82.4%)                  | 0.003                | 6199 (82.4%)                  | 6200 (82.5%)                  | 0.003                |
| Independent                                            | 815 (7.0%)                    | 714 (8.8%)                    | 0.067                | 628 (8.4%)                    | 622 (8.4%)                    | 0.003                |
| Unknown                                                | 1169 (10.0%)                  | 682 (8.4%)                    | 0.055                | 675 (9.0%)                    | 649 (8.6%)                    | 0.014                |
| Atrial fibrillation, atrial flutter (I48)              | -                             | 11,227 (96.2%)                | 0.044                | -                             | 7957 (97.8%)                  | 0.017                |
| Cerebrovascular diseases (I60–69)                      | 10,625 (91.0%)                | 7731 (95.0%)                  | 0.157                | 1048 (9.0%)                   | 405 (5.0%)                   | 0.055                |
| Coagulopathy (D65–69)                                  | 11,565 (99.1%)                | 8015 (99.6%)                  | 0.062                | 1169 (10.0%)                  | 1140 (9.0%)                  | 0.056                |
| Mental disorders (R00–99)                             | 10,265 (91.0%)                | 7373 (95.0%)                  | 0.157                | 983 (9.0%)                    | 405 (5.0%)                   | 0.055                |
| Neurologic diseases (G00–99)                          | 9,989 (87.9%)                 | 6929 (85.8%)                  | 0.062                | 1169 (10.0%)                  | 1140 (9.0%)                  | 0.056                |
| Respiratory diseases (J00–99)                         | 10,767 (92.2%)                | 7562 (95.0%)                  | 0.062                | 1169 (10.0%)                  | 1140 (9.0%)                  | 0.056                |
| Thrombophlebitis (L80)                                 | 996 (7.8%)                    | 574 (7.1%)                    | 0.034                | 1169 (10.0%)                  | 1140 (9.0%)                  | 0.056                |
| Vertebral diseases (M40–54)                           | 11,470 (98.3%)                | 8923 (98.6%)                  | 0.024                | 1169 (10.0%)                  | 1140 (9.0%)                  | 0.056                |

Total Depend: Total Dependent; Partial Depend: Partial dependent; Surgical Cost was calculated at a rate of 1 US$ = 100 Yen.
groups. After propensity score matching, the distributions of the patient background variables were well balanced between the general and spinal anesthesia groups.

After propensity score matching, the frequencies of aspiration pneumonia in the general and spinal anesthesia groups were 1.8% and 1.5%, respectively ($p = 0.158$). The frequencies of other pulmonary complications (pneumonia, bronchitis, atelectasis, pneumothorax, pulmonary edema, and pulmonary embolism) in the general and spinal anesthesia groups were 1.5% and 1.5%, respectively ($p = 0.893$). The mortalities in the general and spinal anesthesia groups were 1.4% and 1.2%, respectively ($p = 0.219$). The type of anesthesia was not associated with the occurrences of aspiration pneumonia, other pulmonary complications, or mortality in the hospital (Table 2). Of the 15,038 patients who matched the propensity score, 246 had aspiration pneumonia. The percentage of patients who always required assistance with eating before admission was 48% in patients with aspiration pneumonia and 31% in patients without aspiration pneumonia ($p < 0.01$).

According to the instrumental variable analysis results, the mean proportion of patients who received general anesthesia was 80.0% among those admitted to hospitals with higher proportions of general anesthesia and 28.6% among those admitted to hospitals with lower proportions of general anesthesia. The F-statistic was 4,427, suggesting a strong instrument. In the two-stage residual inclusion model, the anesthesia method was not associated with aspiration pneumonia ($p = 0.086$). The anesthesia method was also not associated with other pulmonary complications ($p = 0.922$) or death ($p = 0.780$) (Table 2).

The results of the multivariable logistic regression analysis showed that advanced age, male sex, lower BMI, cerebrovascular disease, dementia, and ADL dependency (eating) were associated with the occurrence of aspiration pneumonia (Table 3). Compared with patients in their 60s or 70s, patients in their 80s and ≥90s had nearly 1.6-fold and 2.3-fold higher odds of aspiration pneumonia, respectively. Male patients had more than 3-fold higher odds of aspiration pneumonia compared with female patients. Patients with a BMI <18.5 kg/m² had 1.5-fold higher odds of aspiration pneumonia compared with patients with a normal BMI. Compared with patients without cerebrovascular disease and dementia, patients with cerebrovascular disease and dementia had nearly 1.7-fold and 1.9-fold higher odds of aspiration pneumonia, respectively. However, Parkinson disease/syndrome and anesthesia types were not associated with the occurrence of aspiration pneumonia. Patients always needing eating assistance had about 1.8-fold higher odds of aspiration pneumonia compared with patients with the ability to eat independently.

Discussion

To our knowledge, three groups have investigated aspiration pneumonia in hip fracture surgery. In two of the three studies, the incidence of aspiration pneumonia was not related to the anesthesia method, which is consistent with our results. In the third study, the effects of the anesthesia method in the development of aspiration pneumonia were not investigated. The frequency of aspiration pneumonia is affected by the diagnosis method (e.g., a radiologic study). One large study used the diagnosis code like we did, and the frequency of aspiration pneumonia occurrence in that study was similar to the frequency of aspiration pneumonia occurrence in our study.

Many studies have not focused on aspiration pneumonia and instead have investigated the relationships between different anesthesia methods and pulmonary complications and mortality in hip surgery. By looking at the research target years of these studies in chronological order, it can be seen that the evaluation of anesthesia methods has changed since around 2010. Older retrospective studies have shown that general anesthesia has higher incidences of pulmonary complications and mortality than local anesthesia. However, recent retrospective studies have shown that neither method of anesthesia has a significant effect on mortality or pulmonary complications. Furthermore, recent prospective studies have shown no significant association between the anesthesia method and the incidence of pneumonia or mortality in hip fracture surgery. The results of the present study are consistent with the results of these recent reports. In the present study, the frequencies of atelectasis, pneumothorax, and pulmonary edema were very low, and there were no significant differences between the anesthesia groups. We could not find any previous reports mentioning these complications, probably because of their low frequencies. Regarding pulmonary embolism, two studies reported that there was no significant difference due to the anesthesia method.

There are several possible reasons why there was no significant difference in the incidence of aspiration pneumonia between the general and spinal anesthesia groups in this study. First, the present study showed that the eating dependence rates for patients with and without aspiration pneumonia were 48% and 31%, respectively: that is, patients who had eaten dependently before admission were more likely to develop aspiration pneumonia. Preoperative ADL abilities (especially eating) are important for maintaining the airway protective reflex and swallowing function. Adjusting for preoperative ADL independence may be one of the reasons why there was no significant difference in the incidence of aspiration pneumonia between the two groups in this study. Second, it was presumed that the start time of oral intake of water and food after surgery was adjusted according to each patient’s condition. Such clinical adjustments may be another reason why there was no significant difference in the incidence of aspiration pneumonia between the two groups. Third, the anesthetics used in recent years are eliminated from the body extremely.
quickly.11–13 Sevoflurane and desflurane allow for rapid recovery from anesthesia due to their low blood and tissue solubility.11,12,33 Even elderly people have fewer than 15 min to extubate and fewer than about 20 min to recover orientation (location, time, and date).34 Remifentanil is rapidly hydrolyzed by blood and tissue esterases and becomes metabolites with very low potency, so the action of remifentanil disappears in about 10 min, even after long-term use, regardless of liver function and age.13,35 In Japan, sevoflurane has been clinically available since the 1990s, while remifentanil has been available since 2007, and desflurane since 2011. Residual neuromuscular blockers are associated with an increased risk of postoperative pulmonary complications.36,37 Sugammadex, which can antagonize muscle relaxants quickly and completely compared to traditional anticholinesterases, has been in clinical use in Japan since 2010 and is currently used in more than 90% of cases.38–40 Since this study used data from 2010 to 2019, it might be inferred that these short-acting anesthetics and sugammadex reduced the incidence of aspiration pneumonia after general anesthesia. The use of short-acting anesthetics and sugammadex is widespread worldwide. The results of recent retrospective and prospective studies may support this third reason.27–30 Fourth, many elderly patients with hip fractures are frail and suffer from cognitive impairment or chronic constipation. In frail patients, the muscles used to exhale vomit are presumed to be weak. Past literature has asserted that coughing and swallowing are controlled primarily by the brainstem; however, recent studies have reported that the cortical and subcortical structures play critical roles in the airway protective reflex.41,42 If this theory is correct, then patients with cognitive impairments, whose brains are atrophying, are likely to be prone to aspiration. Furthermore, chronic constipation is associated with ileus.43 If ileus occurs, there is an increased risk of vomiting. Therefore, hip fracture patients are speculated to be more likely to develop aspiration pneumonia due to their deteriorating physical strength and their health conditions.13–45 These overwhelming factors may have negated the slight difference between anesthesia methods and might have resulted in the lack of a significant difference in the incidence of aspiration pneumonia between the general and spinal anesthesia groups in this study.

In the multivariable analysis, the age and BMI results were consistent with a previous report that older age and lower BMI are associated with the development of aspiration pneumonia.1,2,20–22 So far, no consistent results have been reported regarding the effects of sex.1,2,21 The distance between the hyoid bone and the mandible increases with aging more in males than in females.46 This change in the position of the hyoid bone indicates atrophy of the surrounding muscles, and it narrows the space in the larynx, impairing safe swallowing movements. We think that this may be one of the reasons why males had more occurrences of aspiration pneumonia than females. When it comes to the presence of Parkinson disease/syndrome, it is unclear why there was no significant difference in the occurrence of aspiration pneumonia. The occurrence of a hip fracture means that the patient was able to walk or stand. At that stage, patients with Parkinson disease/syndrome may still have relatively mild dysphagia. Assessment of swallowing ability and intervention by a speech therapist can reduce postoperative pneumonia.47,48 These techniques should be used to prevent aspiration pneumonia, especially in high-risk patients: male sex, ≥ 80 years of age, low BMI, cerebrovascular disease, dementia, and need for eating assistance.

Several limitations should be noted. First, the results of the present study are limited by the retrospective study design. Since only in-hospital information was available, complications after discharge were not involved. However, Japanese insurance systems allow patients to stay in the hospital longer than North American systems. In the present study, the mean

### Table 2. Associations between anesthetic methods and outcomes.

| Outcomes (ICD-10 code) | General (n = 7519) | Spinal (n = 7519) | Logistic regression analysis | Instrumental variable analysis |
|------------------------|-------------------|------------------|-------------------------------|-------------------------------|
|                        |                   |                  | OR (95% CI)                   | OR (95% CI)                   |
| Aspiration pneumonia   | 1.8% (134)        | 1.5% (112)       | 1.200 (0.932–1.545) 0.158    | 1.289 (0.964–1.724) 0.086    |
| Other pulmonary        | 1.5% (114)        | 1.5% (112)       | 1.018 (0.783–1.324) 0.893    | 0.985 (0.731–1.328) 0.922    |
| complications          |                   |                  |                               |                               |
| Pneumonia              | 1.0% (76)         | 0.9% (67)        | 1.136 (0.816–1.580) 0.450    | 1.156 (0.78–1.712) 0.470     |
| Bronchitis             | 0.2% (14)         | 0.2% (13)        | 1.077 (0.506–2.293) 0.847    | 0.91 (0.44–1.882) 0.799      |
| Atelectasis            | 0% (2)            | 0% (3)           | 0.667 (0.111–3.990) 0.657    | 1.066 (0.19–5.984) 0.942     |
| Pneumothorax           | 0% (1)            | 0.1% (4)         | 0.250 (0.028–2.236) 0.215    | 0.322 (0.069–1.594) 0.168    |
| Pulmonary edema        | 0.1% (5)          | 0% (3)           | 1.667 (0.398–6.978) 0.484    | 2.763 (0.65–11.737) 0.169    |
| Pulmonary embolism     | 0.3% (19)         | 0.3% (22)        | 0.863 (0.467–1.596) 0.639    | 0.695 (0.353–1.367) 0.292    |
| Death                  | 1.4% (105)        | 1.2% (88)        | 1.196 (0.899–1.590) 0.219    | 1.053 (0.733–1.513) 0.780    |

Instrumental variable analyses using the ratio of general anesthesia and spinal anesthesia performed at each hospital between 1 April 2019 and 31 March 2020 as an instrumental variable were performed, and odds ratio (OR) and their 95% confidence interval (CI) were determined using a two-stage, residual inclusion model.
postoperative hospitalization period was 27 ± 19 days, which was longer than the period of 7 ± 10 days in the study by Studer et al.3; therefore, we do not think the observation period was short. Second, we did not know when aspiration pneumonia developed because the days of disease onset were not recorded in the DPC database. Therefore, to exclude cases in which aspiration pneumonia developed before surgery, we included only cases in which surgery was performed within 4 days, including the day of hospitalization; we assumed that if patients were expected to develop aspiration pneumonia, then their hip fracture surgeries were postponed and treatment for aspiration pneumonia was prioritized. Furthermore, the instrumental variable method is a method of using instrumental variables to perform a retrospective observational study similar to a randomized controlled trial.49 The results of both the propensity score analysis and the instrumental variable method were similar, demonstrating the robustness of the results of this study. However, prospective investigations are needed because this study could not determine whether aspiration pneumonia occurred soon after surgery or a few days later. Third, some patients with femoral fractures cannot undergo femoral surgery immediately after hospitalization because they are undergoing antithrombotic therapy or have problems such as cardiac function problems, poor control of diabetes mellitus, or concomitant trauma. Excluding these patients in this study may have resulted in low rates of aspiration pneumonia and mortality. Fourth, as the study population was primarily Japanese, the results may not be generalizable to people in other countries.

**Conclusion**

The incidence of aspiration pneumonia was not significantly different between general and spinal anesthesia in elderly hip fracture surgery patients. The incidence of aspiration pneumonia was 1.8% (total of general and spinal anesthesia). The study excluded critically ill patients who could not undergo surgery immediately after admission; the actual incidence of aspiration pneumonia may have exceeded 1.8%. Predictive factors of aspiration pneumonia were advanced age, male sex, lean body, cerebrovascular disease, dementia, and ADL dependency (eating). Regardless of the anesthesia method, great care should be taken to prevent postoperative aspiration pneumonia, especially in elderly patients with these predictive factors.

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