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Usefulness of Jackson mask ventilation during bronchoscopy in patients with acute respiratory failure

A retrospective review

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Abstract

Bronchoscopy is a procedure for diagnosis and treatment decision-making in patients with lung disease, especially those with acute respiratory failure. However, the optimal bronchoscopic method for patients with acute respiratory failure is not known. Therefore, in the real world, we sometimes hesitate to perform bronchoscopy in such patients because of safety and have experienced treating patients without bronchoscopy. To address this problem, we evaluated the usefulness and safety of Jackson mask ventilation, a novel noninvasive method of bronchoscopy performed under mask ventilation using the Jackson Rees circuit, in patients with acute respiratory failure.

We retrospectively reviewed patients with acute respiratory failure who underwent bronchoscopy at our institution between January 2015 and May 2018. We compared patients who received Jackson mask ventilation (Jackson group) and those who received conventional oxygen administration (conventional group). Mean percutaneous oxygen saturation (SpO_2) and mean oxygen flow rate were compared between the groups by the Wilcoxon signed-rank test. We excluded patients who were intubated and those without acute respiratory failure who received Jackson mask ventilation preventively.

Of 1262 patients who underwent bronchoscopy, 12 were classified into the Jackson group and 13 into the conventional group. Proper oxygenation was maintained in the Jackson group, with SpO_2 increasing after Jackson mask ventilation (89.4% to 96.8%, $P=.03$). Mean SpO_2 was significantly higher in the Jackson group than in the conventional group (96.8% vs 95.2%, $P=.03$). Mean oxygen flow rate was significantly lower in the Jackson group (4.0 L/min vs 7.9 L/min, $P<.001$). There was no significant difference in safety.

Our findings suggest that Jackson mask ventilation is safe and effective when performing bronchoscopy in patients with acute respiratory failure. Jackson mask ventilation maintained proper oxygenation and decreased the oxygen flow rate compared with the conventional method. Using Jackson mask ventilation, we could perform bronchoscopy safely and effectively in patients with acute respiratory failure, including some who had unstable respiratory status. (UMIN000038481).

Abbreviations: ARF = acute respiratory failure, BAL = bronchoalveolar lavage, HFNC = high-flow nasal cannula, NPPV = noninvasive positive pressure ventilation, PEEP = positive end-expiratory pressure, SpO_2 = percutaneous oxygen saturation.

Keywords: acute respiratory failure, bronchoscopy, Jackson mask ventilation, Jackson rees circuit, novel noninvasive method

Editor: Davor Plavec.

A summary of this paper was presented at the 24th Congress of the Asian Pacific Society of Respirology, held on November 14–17, 2019, in Hanoi, Vietnam.

The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the amended Declaration of Helsinki. The study protocol was approved by Certified Review Board of National Center for Global Health and Medicine (NCGM-G-003359-00) and registered in the UMIN Clinical Trials Registry (UMIN000038481). Patients were provided an information disclosure document explaining the study and were excluded from the analysis if they opted out.

The authors have no funding and conflicts of interests to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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How to cite this article: Takumida H, Suzuki M, Suzuki T, Sakamoto K, Hashimoto M, Ishii S, Naka G, Iikura M, Izumi S, Takeda Y, Hojo M, Sugiyama H. Usefulness of Jackson mask ventilation during bronchoscopy in patients with acute respiratory failure: a retrospective review. Medicine 2021;100:46(e27943).

Received: 6 April 2021 / Received in final form: 27 October 2021 / Accepted: 3 November 2021

http://dx.doi.org/10.1097/MD.0000000000027943

1. Introduction

Bronchoscopic examination is a critical procedure for confirmatory diagnosis and treatment decision-making in patients with lung disease, especially those with acute respiratory failure (ARF). Hisanaga et al reported that bronchoalveolar lavage (BAL) could be beneficial in the management of patients with acute respiratory distress syndrome.[1] However, no in-depth clinical studies have investigated the optimal method of bronchoscopy in patients with ARF because of the challenges involved in performing bronchoscopy in patients with unstable respiratory status. The British Thoracic Society guideline recommends oxygen supplementation in patients with a significant change in arterial oxygen saturation or with respiratory failure. However, it does not describe a particular method for oxygen administration during bronchoscopy in patients with ARF.[2] Therefore, the methods used differ among facilities depending on local availability and expertise.

Standard bronchoscope insertion leads to a reduction of about 10 mm Hg in partial pressure of oxygen in arterial blood.[3] However, this reported decrease does not include the effects of sedation[4] or BAL,[5] which can cause more severe hypoxia. Therefore, we sometimes hesitate to perform bronchoscopy in patients with ARF for reasons of safety and have been searching for safer ways of performing BAL, transbronchial lung biopsy/transbronchial biopsy, and transbronchial needle aspiration. There have been reports on the usefulness of noninvasive positive pressure ventilation (NPPV) and high-flow nasal cannula (HFNC) during bronchoscopy in patients with ARF in whom conventional methods such as nasal cannulation and oxygen masks are ineffective.[6–9] Typically, patients tolerate HFNC better than NPPV and proper oxygenation can be maintained using it. However, during bronchoscopy we cannot administer positive end-expiratory pressure (PEEP) as an additional effect of HFNC because the patient's mouth is open.[9] Also, when using NPPV and wanting to suction oral secretions such as sputum or saliva that could cause a rapid decrease in percutaneous oxygen saturation (SpO_2), we often have to remove the mask to do this, making the procedure more complicated. In both cases, we cannot address this rapid decline in oxygenation because of the time needed to start the machines. Both machines require considerable space and are rarely kept in the bronchoscopy examination room.

To address this problem, Suzuki et al previously proposed a novel non-invasive method of bronchoscopy performed under mask ventilation using the Jackson Rees circuit that we called Jackson mask ventilation (Fig. 1).[10] Hand mask ventilation using a Jackson Rees circuit uses an L-shaped connector and a non-self-inflating bag, also known as a Mapleson F circuit. This type of circuit provides a high concentration of oxygen and ventilation maintaining positive airway pressure by adjusting the gas discharge valve. This ventilation method has been widely used in situations requiring management of respiratory failure, such as during anesthesia, artificial respiration during emergency resuscitation, and transportation of patients requiring ventilatory management. Suzuki et al. previously suggested the Jackson Rees circuit might improve the oxygenation to a greater degree than conventional methods and might be more cost-effective than NPPV and HFNC.[10]

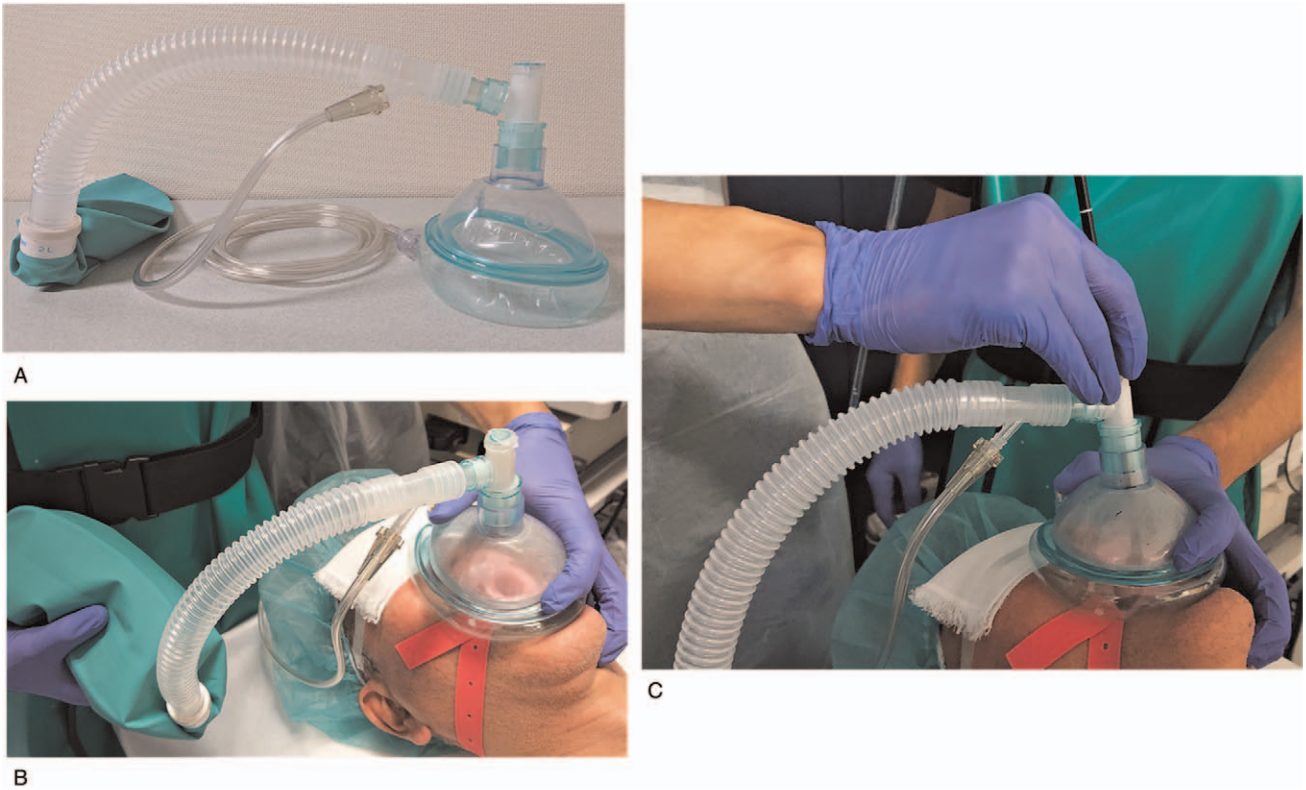

Figure 1. Clinical photographs showing bronchoscopy using Jackson mask ventilation. (A) Configuration of Jackson mask ventilation. (B) The patient's mouth is covered with the mask, which is then connected to the Jackson Rees circuit. (C) The bronchoscope is inserted through the Y connector and mouthpiece.

In this study, we compared the usefulness and safety of Jackson mask ventilation with those of a conventional method in patients with ARF undergoing bronchoscopy. Specially, we examined the hypotheses that Jackson mask ventilation would improve oxygen saturation, reduce oxygen flow rate, and have similar safety in comparison with conventional oxygen administration. We present the following article in accordance with the STROBE reporting checklist.

2. Materials and methods

2.1. Study design and patients

We retrospectively reviewed patients with ARF aged ≥18 years who underwent bronchoscopy using Jackson mask ventilation at our institution between January 2015 to May 2018 (Jackson group). ARF was defined as $SpO_2 < 90\%$ under an oxygen flow rate of 4 L/min as a result of primary disease, intravenous anesthesia, or procedures. This oxygen status corresponds to the ratio of the partial pressure of oxygen in arterial blood to the fraction of inspiratory oxygen being 200, based on the Berlin Definition of moderate acute respiratory distress syndrome.[11] These patients were then compared with a control group comprising patients aged ≥18 years who had the same severity of ARF and underwent bronchoscopy using conventional oxygen administration (conventional group) during the study period. The primary endpoint was oxygenation, and the secondary endpoints were oxygen flow rate used to maintain oxygenation in bronchoscopy and safety of bronchoscopy. Safety was assessed in terms of sedation dose, procedure time, and postoperative complications. We excluded intubated patients firstly because they included a mix of patients with uncontrollable ARF and those undergoing interventional procedure (ex. removal of a tracheal foreign body or balloon dilatation) and secondly because we wanted to evaluate the effect of only Jackson mask ventilation. We also excluded patients without ARF who received Jackson mask ventilation preventively. The Jackson group comprised patients who had ARF before or during bronchoscopy and for whom continuing the examination with conventional oxygen administration was judged to be unsafe. Patients in the conventional group were limited to those who had ARF before bronchoscopy in order to exclude patients with mild transient ARF.

2.2. Bronchial examination

Bronchoscopy was performed as follows. Hydroxyzine 25 mg and atropine 0.5 mg were injected intramuscularly before the procedure. The patient then inhaled 10 ml of lidocaine 2%. The same dose of lidocaine was used for local anesthesia during bronchoscopy. Midazolam 0.03 to 0.04 mg/kg was slowly administered intravenously for sedation.[12] An additional dose (0.04–0.15 mg/kg) was administered as needed to maintain a Richmond Agitation-Sedation Scale score between 0 and −2. In the conventional method, oxygen up to 15 L/min was administered via a nasal cannula or mask to maintain $SpO_2 > 90\%$. Jackson mask ventilation was started when the conventional method was unable to maintain $SpO_2 > 90\%$.

Jackson mask ventilation was performed by an assistant doctor with advanced training in cardiac life support under the supervision of a respiratory physician specialized in intensive care. The assistant doctor fitted the mask manually, maintained the airway, and adjusted the ventilation settings. When switching to Jackson mask ventilation from the conventional method during the procedure, the oxygen flow rate was initially the same (up to 15 L/min) and then gradually decreased while maintaining $SpO_2 > 95\%$. When Jackson mask ventilation was started before the procedure, the oxygen flow rate was set at 10 L/min initially and was gradually decreased using the same method. When oxygenation was stable, the oxygen flow rate was decreased to 2 to 4 L/min.

2.3. Data collection

SpO_2 and oxygen flow rate were monitored continuously during bronchoscopy and were routinely recorded, along with blood pressure, at 5-min intervals in the medical records. We calculated mean values before and after Jackson mask ventilation. The patients were then followed until the end of oxygen administration to evaluate outcomes.

2.4. Study size

We have performed a total of about 360 bronchoscopy procedures among all patients admitted to the department of respiratory medicine at our hospital each year. In our experience, patients with ARF comprise about 2% of these patients. Because we reviewed patients during the 3.5 years between January 2015 and May 2018, the number of target cases was 25.

2.5. Statistical analysis

Background characteristics and procedural data were compared between the Jackson group and conventional group using Fisher exact test for categorical variables (shown as the number and percent) or the Wilcoxon signed-rank test for continuous variables (shown as the mean and range). Mean SpO_2 and mean oxygen flow rate were compared between the groups by the Wilcoxon signed-rank test. All missing data were excluded from the analysis. Because the number of cases was small, we did not perform any sensitivity analyses. All statistical analyses were performed using EZR (Easy R) statistical software version 1.40 (available at http://www.jichi.ac.jp/saitama-sct/SaitamaHP.files/statmed.html).[13] A P value <.05 was considered statistically significant.

2.6. Ethical approval

This study was conducted in accordance with the amended Declaration of Helsinki. The study protocol was approved by our institutional review board (NCGM-G-003359-00) and registered in the UMIN Clinical Trials Registry (UMIN000038481). Patients were provided an information disclosure document explaining the study and were excluded from the analysis if they opted out.

3. Results

A total of 1262 patients underwent bronchoscopy during the study period and 36 patients were excluded because of intubation. A Jackson Rees circuit was used in 15 of the remaining patients. Three patients were excluded because of the preventive use of Jackson mask ventilation, leaving 12 patients in the Jackson group. The conventional group consisted of 13 patients with ARF who underwent bronchoscopy without the Jackson Rees circuit (Fig. 2).

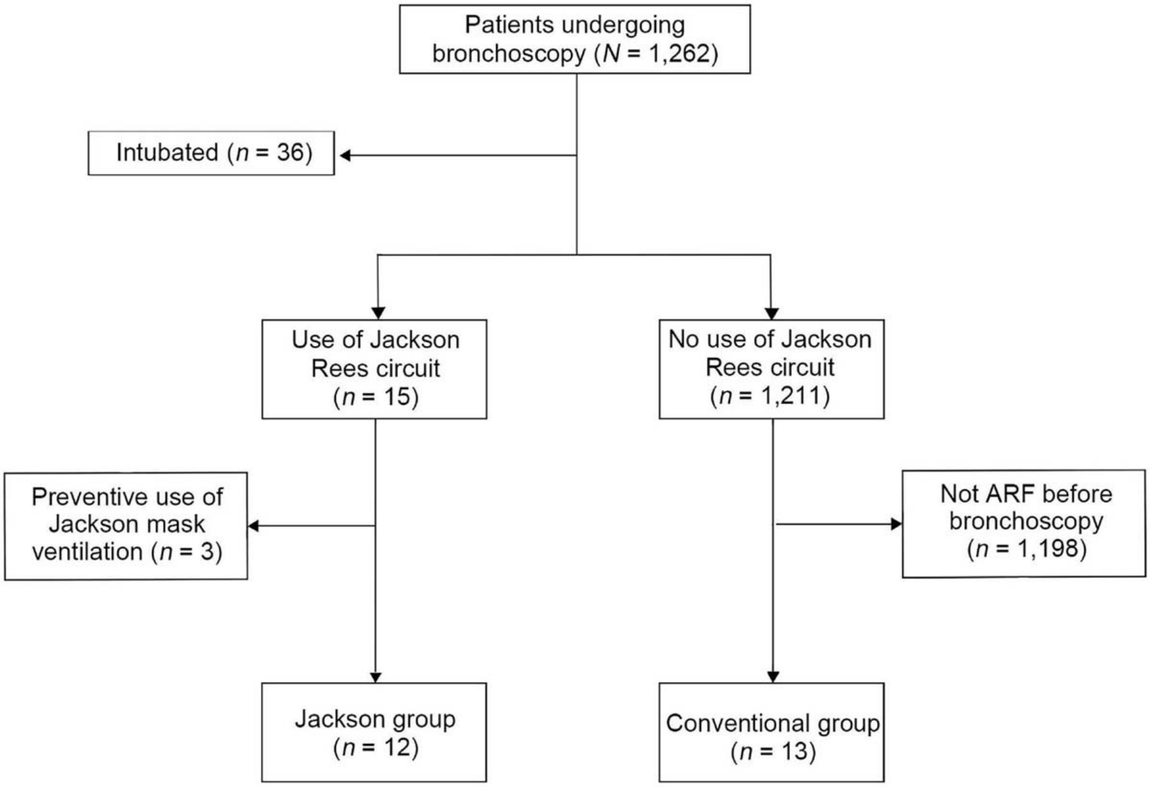

Figure 2. Patient selection. In total, 1,262 patients underwent bronchoscopy at our institution between January 2015 and May 2018. Patients with ARF (SpO_2 < 90% under an oxygen flow rate of 4 L/min) were divided according to the method of oxygen administration into a Jackson mask ventilation group (Jackson group, n = 12) and control group (conventional group, n = 13). Intubated patients and patients receiving Jackson mask ventilation preventively were excluded. ARF = acute respiratory failure, SpO_2 = percutaneous oxygen saturation.

Table 1

Demographics and clinical characteristics at baseline.

Characteristic	Jackson group (n = 12)	Conventional group (n = 13)
Male sex, n (%)	8 (75.0)	11 (84.6)
Age, median (range), yr	69.0 (40.0–85.0)	68.5 (18.0–93.0)
Smoking status, n (%)†		
Current or former	6 (50.0)	7 (53.8)
Never	6 (50.0)	4 (30.8)
NPPV before bronchoscopy, n (%)	2 (16.7)	0 (0.0)
Median oxygen flow rate before bronchoscopy (range), L/min*	3.5 (0.0–6.0)	4.0 (4.0–8.0)
Suspected disease, n (%)‡		
Lung cancer	2 (16.6)	5 (38.5)
Interstitial pneumonia	7 (58.3)	4 (30.8)
Infection	2 (16.6)	3 (23.1)
Other	1 (8.3)	1 (7.7)
Procedure, n (%)‡		
BAL/wash	8 (75.0)	7 (53.8)
TBLB/TBB	8 (75.0)	6 (46.1)
TBNA	1 (8.3)	3 (23.1)
Toileting	3 (25.0)	2 (15.4)
Follow up time, median (range), days	29 (7–104)	20 (6–91)

BAL = bronchioalveolar lavage, NPPV = noninvasive positive pressure ventilation, TBB = transbronchial biopsy, TBNA = transbronchial needle aspiration.

† Two patients in the conventional group had unknown smoking history.

‡ Totals are greater than 100% because of suspected comorbidities in the conventional groups. And multiple bronchoscopy procedures in both groups.

* Marginally significant difference between the 2 groups (P = .02, Wilcoxon signed-rank test). Two patients who received NPPV before bronchoscopy in the Jackson group were excluded from the calculation of median oxygen flow rate because the calculation was not possible. The settings for these patients were as follows: One was on continuous positive airway pressure with positive end-expiratory pressure of 8 cm H_2O and FiO_2 of 30%. The other was on bilevel NPPV with inspiratory positive airway pressure of 12 cm H_2O, expiratory positive airway pressure of 5 cm H_2O, and FiO_2 of 60%.

Table 1 shows the demographics and clinical characteristics of patients in each group. In both groups, there was a male predominance and median age was approximately 69 years. A marginally significant difference in median oxygen flow rate before bronchoscopy was noted between the Jackson group and the conventional group (P = .02). There was no significant difference in any of the other parameters between the groups. The median follow-up duration was 23 (range, 6–104) days for all patients.

Mean SpO_2 was significantly increased after Jackson mask ventilation (96.8%) than before (89.4%, P = .03; Fig. 3). Moreover, mean oxygen flow rate was decreased after Jackson mask ventilation, although not significantly (5.2 L/min vs 4.0 L/min, P = .13). Mean SpO_2 was slightly but significantly higher in the Jackson group than in the conventional group (96.8% vs 95.2%, P = .03; Fig. 4A). Mean oxygen flow rate was significantly lower in the Jackson group than in the conventional group (4.0 L/min vs 7.9 L/min, P < .001; Fig. 4B).

The dose of midazolam used for sedation and the procedure time were almost the same in the 2 groups. No patients in either group developed bronchoscopy-related complications, such as pneumothorax or pneumonia. In all cases, a treatment plan was decided based bronchoscopic findings and rapidly implemented. NPPV/HFNC was used in 2 patients in the Jackson group and 3 in the conventional group because of worsening respiratory failure due to primary disease. More patients required mechanical ventilation in the Jackson group, but the difference was not significant. One patient in the Jackson group died during hospitalization due to the primary disease (pneumocystis

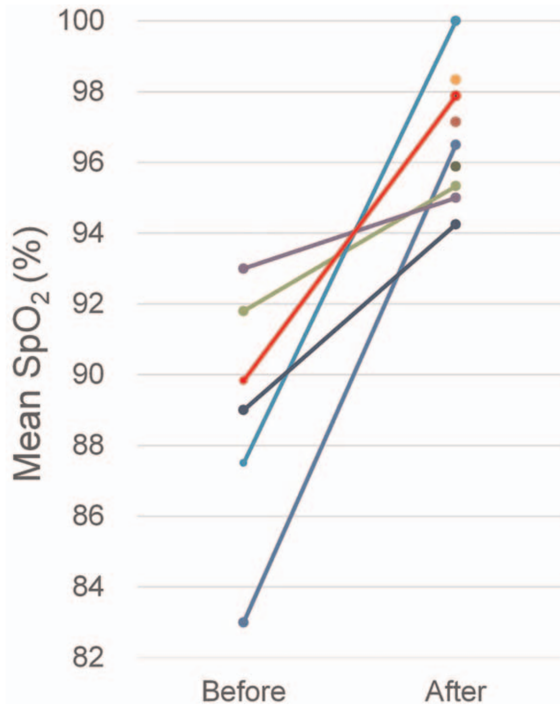

Figure 3. Mean SpO_2 before and after Jackson mask ventilation. Mean SpO_2 during the procedure increased after Jackson mask ventilation (before: 89.4%, n=6; after: 96.8%, n=10; P=.03, Wilcoxon signed-rank test). Note that 2 patients had overlapping mean SpO_2 values after Jackson mask ventilation (red data point: 97.9%). SpO_2=percutaneous oxygen saturation.

pneumonia), and 1 in the conventional group died during hospitalization due to worsening of a comorbid condition (Table 2).

4. Discussion

Bronchoscopy is an essential procedure for diagnosis and treatment decision-making in many lung diseases, but carries a risk of deterioration of oxygenation. A safer bronchoscopy procedure that can maintain oxygenation is needed. Although there have been a few reports of bronchoscopy using Jackson mask ventilation, no case-control study has been performed.

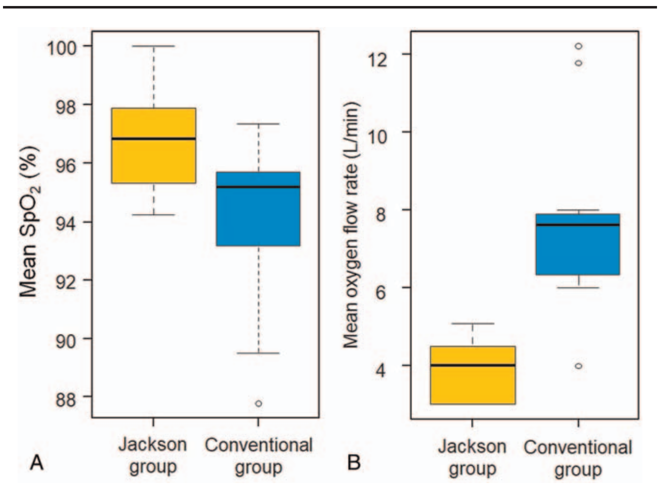

Figure 4. Comparison of SpO_2 and oxygen flow rate during bronchoscopy. We compared the Jackson group (n=10) and the conventional group (n=11). (A) Mean SpO_2 was slightly but significantly higher in the Jackson group (96.8% vs 95.2%, P=.03, Wilcoxon signed-rank test). (B) Mean oxygen flow rate was also significantly lower in the Jackson group (4.0 L/min vs 7.9 L/min, P<.001, Wilcoxon signed-rank test). SpO_2=percutaneous oxygen saturation.

Table 2

Comparison of procedural data in the Jackson mask ventilation group and conventional group.

Variable	Jackson group (n=12)	Conventional group (n=13)
Midazolam for sedation mean (range), mg	3.3 (0.0–6.6)	2.9 (1.0–6.0)
Mean procedure time (range), min	47.5 (36–72)	43.0 (14–55)
NPPV/HFNC after bronchoscopy, n (%)	3 (30.0†)	2 (15.3)
In-hospital deaths, n (%)	1 (8.3)	1 (7.7)

HFNC = high-flow nasal cannula, NPPV = noninvasive positive pressure ventilation.
No significant differences were detected between the groups by Fisher exact test for categorical variables or the Wilcoxon signed-rank test for continuous variables.
†The percentage was calculated after excluding 2 patients who had received NPPV previously.

This study is the first to compare the effectiveness and safety of Jackson mask ventilation with those of conventional ventilation in patients with ARF during bronchoscopy. In this study, the background characteristics and procedures performed in the 2 groups were almost the same. As reported previously,[10] we found that Jackson mask ventilation maintained proper oxygenation, decreased the required oxygen flow rate, and was superior to conventional methods, but had almost the same degree of safety. There were no bronchoscopy-related complications (e.g., pneumonia) in either group. The amount of medication required for sedation during bronchoscopy and the in-hospital death rate were almost the same in both groups.

Our results suggest that the positive airway pressure generated by Jackson mask ventilation improved oxygenation and decreased the required oxygen flow rate compared with the conventional method. Finer et al reported that Jackson mask ventilation administered by an expert could achieve PEEP of 4.2 cm H_2O and peak inspiratory pressure of 26.7 cm H_2O,[4] which improved oxygenation and ventilation during bronchoscopy. Some studies have suggested that bronchoscopy using NPPV/HFNC can maintain oxygenation[6–9] but did not report the required oxygen flow rate. Although Jackson mask ventilation requires an additional doctor during the procedure, it can achieve better oxygenation with a lower oxygen flow rate. Given the large amount of oxygen used in HFNC, Jackson mask ventilation is potentially economically advantageous because of its lower oxygen flow rate.

Jackson mask ventilation can also simplify the procedure for airway management. Laryngeal mask airway and intubation are also reliable techniques for securing the airway, but they stimulate the pharynx, require deeper anesthesia, and add an additional step making the procedure more complicated. We excluded cases that required both intubation and Jackson mask ventilation in this study because our aim was to eliminate the need for additional steps.

We believe that Jackson mask ventilation is as safe as the conventional method. Although mechanical ventilation was used more often in the Jackson group, these patients were also less stable and developed ARF rapidly during bronchoscopy compared with patients in the conventional group. Also, the difference in mechanical ventilation was not statistically significant, though this might have been due to the small sample size. We also attribute this to a temporary increase in required oxygen during BAL, which was performed in all patients who needed

NPPV in both groups. NPPV was administered to prevent exacerbation of respiratory status in the Jackson group and was withdrawn within a few days.

We could not confirm improvement in hypercapnia (an advantage of NPPV and HFNC) using Jackson mask ventilation because we did not measure arterial blood gas or end-tidal carbon dioxide. However, we do not suspect that hypercapnia was a problem because none of the patients stopped breathing spontaneously during bronchoscopy.

Better oxygenation can facilitate stable examination during any lengthy procedure, so we had hoped to assess how many procedures were completed as planned. However, this was not possible because of insufficient data, reflecting the retrospective nature of the research and the fact that bronchoscopy is often performed urgently in patients with ARF. This aspect will be considered in future research.

Patients in whom Jackson mask ventilation was used preventively were excluded from this study. However, our results suggest that preventive use may be valuable. For example, a feature of obstructive sleep apnea is repeated apneic episodes followed by rapid oxygenation, which increases the risk of heart disease.[14] Hypoxemia caused by sedation during bronchoscopy has characteristics similar to those of obstructive sleep apnea. Therefore, we suggest that Jackson mask ventilation, which can produce continuous PEEP and decrease hypoxemia, is appropriate for preventive use. We plan to evaluate the preventive use of this procedure and compare it in a larger sample of patients with the same conditions.

The limitations of this study include its retrospective design, small sample size, incomplete recording of SpO_2 and oxygen flow rates, and inconsistent recording of transient changes. Also, patients with severe respiratory failure requiring intubation were excluded because of safety, so we could not examine the effect of Jackson mask ventilation in this population. Furthermore, the study was performed at a single center, which might have introduced a degree of bias. To exclude patients with mild transient ARF, all patients in the conventional group had ARF before bronchoscopy. Hence, the conditions of the 2 groups were not the same. Nevertheless, our findings could help us to decide which method of oxygen administration to use during bronchoscopy in patients with ARF.

In conclusion, our findings suggest that Jackson mask ventilation is safe and effective in patients with ARF undergoing bronchoscopy. Jackson mask ventilation could maintain proper oxygenation and decrease the required oxygen flow rate compared with the conventional method. However, because we did not compare the 2 methods in the same population, caution is required in interpreting these results. We are planning to examine these findings in a larger study and to compare this method with NPPV and HFNC. Our results suggest that Jackson mask ventilation allows bronchoscopy to be performed effectively and safely in patients with ARF, including those with unstable respiratory status.

Author contributions

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Formal analysis: Hiroshi Takumida.
Investigation: Hiroshi Takumida, Manabu Suzuki, Tomoyuki Suzuki, Keita Sakamoto, Masao Hashimoto, Satoru Ishii, Go Naka, Motoyasu Iikura, Shinyu Izumi, Yuichiro Takeda, Masayuki Hojo, Haruhito Sugiyama.
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Writing – original draft: Hiroshi Takumida, Manabu Suzuki.
Writing – review & editing: Hiroshi Takumida.

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