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정상 기도를 가진 환자에서 마스크 환기 확인 전후에 로큐로니움을 투여했을 때 마스크 환기의 효율성 비교

－무작위대조시험－

Comparison of efficiency of mask ventilation between early and late administration of rocuronium before and after checking mask ventilation in patients with normal airways : a randomized controlled trial

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ABSTRACT

Comparison of efficiency of mask ventilation between early and late administration of rocuronium before and after checking mask ventilation in patients with normal airways : a randomized controlled trial

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Introduction: During induction of general anesthesia, it is common practice to delay neuromuscular blockade until the ability to deliver mask ventilation has been confirmed, however, the benefits of this approach have never been scientifically validated. Thus, the early and late administration of rocuronium before and after checking mask ventilation were compared in patients with

normal airways. The time to tracheal intubation was also compared between groups.

Methods: Patients (n = 114) were randomized to receive intravenous rocuronium either before (early rocuronium group, n = 58) or after (late rocuronium group, n = 56) checking mask ventilation. Expiratory tidal volumes were measured at 10, 20, 30, 40, 50, and 60 s after apnea during mask ventilation. The ease of mask ventilation was graded, and the time from apnea to tracheal intubation was measured. The primary outcome was the mean tidal volume for 60 s of mask ventilation after apnea.

Results: The mean tidal volume was larger in the early rocuronium group than in the late rocuronium group for 60 s of mask ventilation after apnea [552 (165) ml breath^{-1} *vs* 393 (165) ml breath^{-1}, mean difference (95% CI) 160 ml breath^{-1} (98 to 221 ml breath^{-1}), $P < 0.001$, unpaired t-test]. Because the interaction between time and group was significant in the tidal volumes measured for 60 s of mask ventilation ($P < 0.001$, linear mixed effects model), pairwise comparisons were performed at the six time points. The differences in tidal volumes between groups were significant at 10, 20, 30, 40 ($P < 0.001$ each, unpaired t-test), and 50 s ($P = 0.002$) after apnea. The time to tracheal intubation was shorter in the early rocuronium group than in the late rocuronium group [116 (42) s *vs* 195 (41) s, mean difference (95% CI) -79 s (-96 to -64 s), $P < 0.001$].

Conclusions: The early administration of rocuronium before checking mask ventilation showed a larger tidal volume and earlier tracheal intubation than

the late administration of rocuronium after checking mask ventilation in patients with normal airways.

Keywords: mask ventilation, rocuronium, tidal volume, tracheal intubation

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CONTENTS

LIST OF TABLES AND FIGURES

Tables

Figures

INTRODUCTION

After induction of general anesthesia, the patient cannot breathe spontaneously and thus requires assisted ventilation with a facemask. If the mask ventilation is difficult or impossible, a tracheal tube or supraglottic airway should be placed immediately to oxygenate the patient.[1-6] The insertion of these devices can be facilitated by adequate neuromuscular blockade.[5-13] The performance of mask ventilation can also change before and after muscle relaxation.[1,4,14-20] Nevertheless, during induction of general anesthesia, it is common practice to delay neuromuscular blockade until the ability to deliver mask ventilation has been confirmed. However, the benefits of this approach have never been scientifically validated.[1-4,14-17,21-25]

Thus, this study compared the early and late administration of rocuronium before and after testing whether the operator was able to ventilate the lungs using a facemask in patients with normal airways. It was hypothesized that the early administration of rocuronium improves the efficiency of mask ventilation and shortens the time to tracheal intubation compared with the late administration. To objectively assess the efficiency of mask ventilation, expiratory tidal volumes during mask ventilation with pressure-controlled mechanical ventilation were measured. The primary outcome was the mean tidal volume for 60 s of mask ventilation after the onset of apnea and the main secondary outcome was the time from apnea to tracheal intubation, which was selected a priori.

METHODS

Design

This prospective, double-blind, parallel-group, randomized controlled trial was approved by the Institutional Review Board of Seoul National University Hospital (reference number 1707-088-870) and written informed consent was obtained from all subjects participating in the trial. The trial was registered at ClinicalTrials.gov (NCT03270696, principal investigator: Jeong-Hwa Seo, Date of registration: 23 August 2017) prior to patient enrollment. This manuscript adheres to the applicable CONSORT guidelines. Inclusion criteria were patients aged > 20 years with ASA physical status I–III, and undergoing elective abdominal or gynecologic surgery under general anesthesia with orotracheal intubation between September 2017 and January 2018. Exclusion criteria were patients with risk of pulmonary aspiration, allergy to the study drugs, neuromuscular disorders, and predictors of difficult airway such as body mass index ≥ 35 kg m^{-2}; Mallampati class 3 or 4; mass or radiation changes in the neck; limitations in mouth opening, neck extension, or jaw protrusion; and history of snoring or sleep apnea.[9,11,20,26,27]

Patients were randomized into two groups to receive intravenous rocuronium either before (early rocuronium group) or after (late rocuronium group) checking mask ventilation. The allocation sequence was concealed in sealed opaque envelopes and patients were blinded to the group assignment.

A nurse not involved in the study prepared 0.6 mg kg^{-1} of rocuronium

(Esmeron; MSD, Kenilworth, NJ) and the same volume of normal saline (JW Pharmaceutical, Seoul, Korea) in identical syringes. The syringe with rocuronium was labeled as the 'first drug' and the syringe with saline as the 'second drug' in the early rocuronium group, and vice versa in the late rocuronium group. The anesthetic machine (Primus; Dräger, Lübeck, Germany) with the pressure gauge and spirometer was checked and calibrated.

Anesthesia and mask ventilation

Patients were monitored with pulse oximetry, non-invasive blood pressure, electrocardiography, and bispectral index (A-2000 XP; Aspect Medical Systems, Newton, MA). For the neuromuscular monitoring with acceleromyography (TOF-watch Sx; Organon, Dublin, Ireland), two electrodes were attached over the ulnar nerve of the patient's left hand, a temperature sensor on the palm, and an acceleration transducer on the thumb with an elastic adaptor. Patients received forced-air warming (3M Bair Hugger, Eden Prairie, MN) to the whole body at a set temperature of 43℃ during anesthetic induction. The head was placed on a 7-cm height headrest in the supine position.

For preoxygenation, 100% oxygen was supplied through a transparent facemask (900 series; Westmed, Tucson, AZ) at 10 L min^{-1}, and patients breathed with tidal volumes for 3 min.[28] While lactated Ringer's solution (JW Pharmaceutical, Seoul, Korea) was dripping rapidly through an 18-gauge venous cannula in the forearm, lidocaine 30 mg was injected. After 10 s,

fentanyl 1 μg kg^{-1}, propofol 2 mg kg^{-1}, and the first drug was administered sequentially **(Table 1)**.

When the patient did not respond to verbal commands and eyelash reflex, the patient's nose and mouth were sealed with the facemask by using the left hand. The mask was held by the left thumb and index finger forming a C-shape, and its elastomeric cushion created an airtight seal with the patient's face. The left third and fourth fingers were placed on the mandible body and the fifth finger was on the mandible angle to extend the patient's head and to thrust the jaw. The anesthetic machine was set to deliver pressure-controlled ventilation with a peak inspiratory pressure of 15 cmH_2O, a positive end-expiratory pressure of 5 cmH_2O, a respiratory rate of 12 breaths min^{-1}, and an inspiratory-expiratory ratio of 1:2. Sevoflurane 4-6% was supplied with 100% oxygen of 6 L min^{-1}. End-tidal carbon dioxide was measured with a sidestream capnometer (Dräger, Lübeck, Germany).

After adequate mask ventilation was confirmed by the chest movement and upslope of the capnogram, the second drug was given and mask ventilation continued **(Table 1)**. Train-of-four (TOF) count was monitored at the adductor pollicis muscle every 15 s.

At a TOF count of 0 and bispectral index of < 60, the patient's trachea was intubated via direct laryngoscopy with a Macintosh 3 or 4 blade. If the intubation failed, it was retried with direct or video laryngoscopy (C-MAC; Karl Storz, Tuttlingen, Germany) after the tube was shaped like a hockey stick with a stylet. An inner diameter of the tracheal tube (Covidien, Mansfield, MA) was 7.0 mm for women and 7.5 mm for men. Tracheal intubation was

verified by the chest movements and a square-wave capnogram. The tracheal cuff pressure was adjusted to less than 25 cmH_2O.

If mask ventilation or tracheal intubation were impossible, the patient was managed according to the guidelines for unanticipated difficult airway.[5]

Table 1. The study protocol

- Preoxygenation for 3 min
- Intravenous injection of lidocaine 30 mg
- Administration of fentanyl 1 μg kg^{-1} and propofol 2 mg kg^{-1}
- Administration of the first drug[a]
- Detection of apnea and unconsciousness
- Mask ventilation checked with pressure-controlled mode
- Mask ventilation confirmed by chest movements and capnogram
- Administration of the second drug[a]
- Monitoring of train-of-four count = 0 and bispectral index < 60
- Start of direct laryngoscopy
- End of laryngoscopy
- Tracheal intubation confirmed by chest movements and capnogram

[a] The first and second drugs are 0.6 mg kg^{-1} of rocuronium and the same volume of normal saline in the early rocuronium group, respectively, and vice versa in the late rocuronium group.

Outcomes

During the injections of the first and second drugs, the patient's withdrawal movements were graded into four levels: no response, movement of the wrist only, movement of the elbow or shoulder, and movement in more than one extremity and reactions such as discomfort or pain.[29]

During mask ventilation, expiratory tidal volumes, end-tidal concentrations of sevoflurane, and bispectral index values were recorded at 10, 20, 30, 40, 50, and 60 s after detecting apnea. The tidal volume and sevoflurane concentrations were measured with the spirometer and gas analyzer incorporated in the anesthetic machine. The minute volume and the average of tidal volumes for 60 s of mask ventilation were calculated. Mask ventilation was evaluated with a four-point scale: easy ventilation, moderate ventilation with an oropharyngeal airway, difficult ventilation requiring two providers, and impossible ventilation by any methods.[9,11,18,19,27,30,31]

During tracheal intubation, the ease of laryngoscopy, movement or position of the vocal cords, limb movement, and coughing were assessed and each variable was scored as excellent, good or poor conditions. The overall intubation condition was excellent if all variables were excellent, good if all were excellent or good, and poor if any variable was poor.[10,32] Mean blood pressure and heart rate were recorded immediately before intubation and one minute after intubation. The time from apnea to successful intubation and the time for laryngoscopy were measured. The laryngoscopic time was defined as the interval between insertion and removal of the laryngoscope blade in the

mouth. After surgery, patients were transferred to the postanesthesia care unit and were asked whether they had experienced muscle weakness during anesthetic induction.

To quantify the efficiency of mask ventilation, the mean expiratory tidal volume for 60 s after apnea was calculated as the primary outcome. The secondary outcomes were the tidal volume, sevoflurane concentrations, and bispectral index at each measurement time point, minute volume, grade of mask ventilation, time from apnea to intubation, intubation conditions, response to rocuronium injection, and any adverse events during anesthetic induction.

Statistical analysis

The distribution of all continuous data was compatible with a normal distribution and the data are presented as mean (SD). Continuous variables including the primary outcome were compared with unpaired t-tests. Repeatedly measured outcomes were analyzed with linear mixed effects models. A random effect was the subject and fixed effects were time (as a categorical variable), group, and interaction between the time and group. If the interaction was significant, pairwise comparisons were performed at each time point with unpaired t-tests. If no interaction was detected, the main effect of group collapsing over time was reported. A first-order autoregressive correlation structure was assumed to model the within-subject correlation over time.

Categorical variables were presented as a number of patients and were compared with Pearson chi-square test or Fisher's exact test if the expected frequencies were less than 5. A significance criterion was $P < 0.05$ for two-sided analysis and was adjusted to $P < 0.008$ (= 0.05/6) with the Bonferroni correction for pairwise comparisons at the six time points. Mean differences with 95% CIs were calculated for the primary outcome and the secondary outcomes including the tidal volume at each time point, minute volume, and the time from apnea to intubation.

In the pilot study for patients with normal airways (n = 10), the mean tidal volume for 60 s after apnea was 341 (186) ml $breath^{-1}$ when rocuronium was given after checking mask ventilation with the pressure-controlled mode. Considering a 30% difference in the tidal volume, 53 patients were needed in each group with an α of 0.05 and a power of 0.8 for two-sided analysis. STATA (Special Edition 14.2; Stata Corporation, College Station, TX) was used for statistical and power analysis and group randomization.

RESULTS

After screening 116 patients, 114 patients were randomized to the early (n = 58) and late (n = 56) rocuronium groups. Some data were missed at 50 and 60 s after apnea because mask ventilation ended before these time points **(Fig. 1)**. There were no apparent clinically important differences in baseline patient characteristics **(Table 2)**. By using the linear mixed effects model, no significant differences were found in the sevoflurane concentrations ($P = 0.241$ for the interaction between time and group; $P = 0.317$ for the main effect of group collapsing over time) and the bispectral index values ($P = 0.758$; $P = 0.860$) during mask ventilation.

Mask ventilation was easy or moderate in all patients. For 60 s of mask ventilation after apnea, the mean tidal volume (primary outcome, $P < 0.001$) and minute volume ($P = 0.001$) were larger in the early rocuronium group than in the late rocuronium group **(Table 3)**. Because the interaction between time and group was significant in the tidal volumes measured for 60 s of mask ventilation ($P < 0.001$), pairwise comparisons were performed at the six time points. The differences in the tidal volume were significant at 10, 20, 30, 40, and 50 s after apnea between groups **(Fig. 2)**. No differences were found in the grade of mask ventilation and response to rocuronium injection **(Table 3)**. Tracheal intubation was achieved with direct laryngoscopy at the first attempt and the intubation condition was excellent or good in all patients. The time from apnea to intubation was shorter in the early rocuronium group than in the

late rocuronium group (**Table 3**; $P < 0.001$). There were no differences in the laryngoscopic time, intubation conditions, and blood pressure or heart rate before and after intubation **(Table 3)**. No patient had any complications or the recall of muscle weakness during mask ventilation and tracheal intubation.

Table 2. Patient characteristics and drug doses for anesthetic induction

	Early rocuronium group (n = 58)	Late rocuronium group (n = 56)
Age (year)	57 (12)	59 (12)
Female	25	33
Weight (kg)	62 (11)	61 (12)
Height (cm)	163 (8)	162 (9)
Body mass index (kg m^{-2})	23.2 (3.0)	23.1 (3.3)
ASA physical status (I/II)	27/31	21/35
Mallampati class (1/2)	42/16	45/11
Fentanyl (μg)	60 (9)	59 (10)
Propofol (mg)	123 (18)	120 (20)
Rocuronium (mg)	36 (5)	34 (6)

Data are the number of patients or mean (SD). There are no differences between groups.

Table 3. Outcomes during mask ventilation and tracheal intubation

	Early rocuronium group (n = 58)	Late rocuronium group (n = 56)	*P*-value
Mean tidal volume (ml breath^{-1})[a]	552 (165)	393 (165)	< 0.001
Minute volume (L min^{-1})[b]	5.8 (2.3)	4.5 (1.9)	0.001
Grade of mask ventilation (easy/moderate)	53/5	54/2	0.439
Response to rocuronium injection (none/wrist movement)	54/4	51/5	0.740
Laryngoscopic time (s)	17 (13)	16 (5)	0.612
Time from apnea to intubation (s)[c]	116 (42)	195 (41)	< 0.001
Cormack-Lehane grade (1/2)	49/9	53/3	0.125
Intubation conditions (excellent/good)	53/5	49/7	0.500
Ease of laryngoscopy (excellent/good)	57/1	54/2	0.615
Movement or position of the vocal cords (excellent/good)	55/3	53/3	> 0.999
Limb movement (excellent/good)	57/1	53/3	0.360
Coughing (excellent/good)	53/5	49/7	0.500
Mean blood pressure before intubation (mm Hg)	87 (18)	93 (19)	0.095
Mean blood pressure after intubation (mm Hg)	101 (21)	98 (15)	0.994
Heart rate before intubation (beats min^{-1})	73 (13)	75 (13)	0.375
Heart rate after intubation (beats min^{-1})	75 (14)	78 (12)	0.217

Data are the number of patients or mean (SD).

[a] The average of expiratory tidal volumes for 60 s of mask ventilation after apnea. Mean difference (95% CI) 160 ml breath^{-1} (98 to 221 ml breath^{-1}), unpaired t-test;

[b] For 60 s of mask ventilation after apnea. 1.3 L min^{-1} (0.5 to 2.1 L min^{-1});

[c] -79 s (-95 to -64 s).

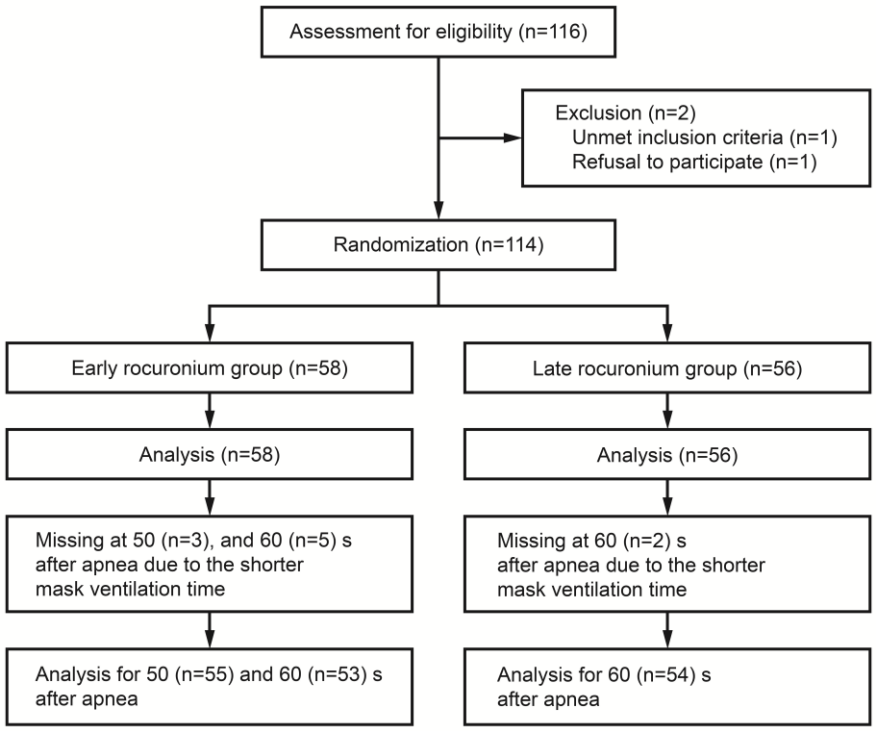

Figure 1. Consolidated Standards of Reporting Trials (CONSORT) diagram

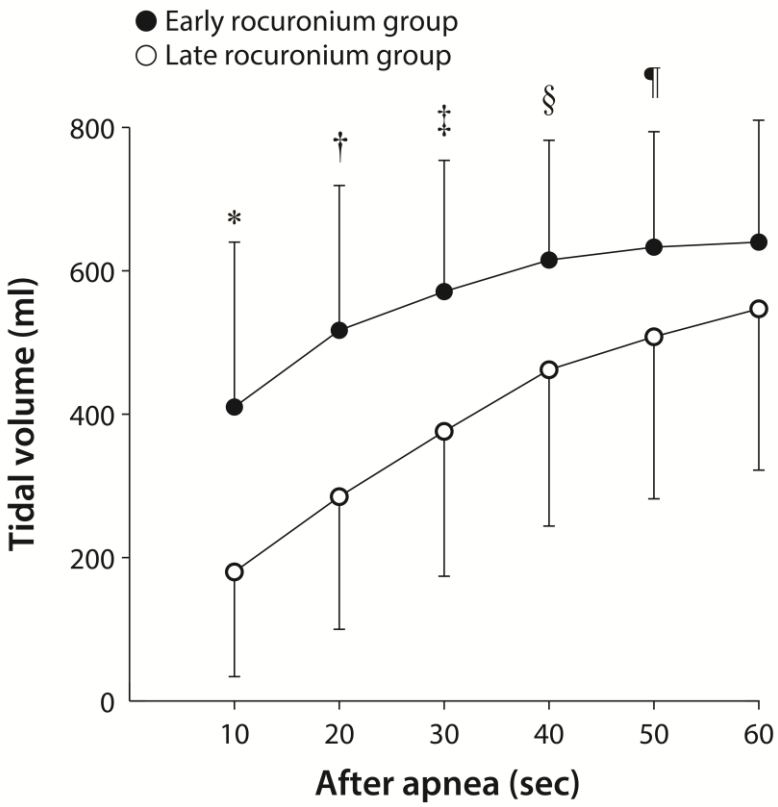

Figure 2. Expiratory tidal volumes during mask ventilation at 10, 20, 30, 40, 50, and 60 s after apnea. The circle is mean and the error bar is SD. The significance criterion is $P < 0.008$ (= 0.05/6) for pairwise comparisons at the six time points.

*Mean difference (95% CI) 230 ml (158-302 ml), $P < 0.001$ compared with the late rocuronium group, unpaired t-test;

†232 ml (160 to 304 ml), $P < 0.001$;

‡194 ml (122 to 267 ml), $P < 0.001$;

§154 ml (77 to 230 ml), $P < 0.001$;

¶125 ml (47 to 202 ml), $P = 0.002$

DISCUSSION

This study showed larger tidal volumes during mask ventilation with pressure-controlled mechanical ventilation and earlier tracheal intubation in the early rocuronium group than in the late rocuronium group.

There are controversies about the effects of neuromuscular blockade on mask ventilation.[1,4,14-20,33,34] Three crossover studies[19,20,31] reported larger tidal volumes after giving rocuronium or vecuronium, but another two crossover studies[33,34] found no difference in the tidal volumes before and after giving the muscle relaxants. However, these studies did not randomize the order of comparative interventions, and neuromuscular blockade was achieved later when anesthesia was more profound. Anesthetic depth is known to affect mask ventilation[19,20,31,35,36] and thus may bias these previous findings. Moreover, a previous randomized study[18] only compared neuromuscular blockade with no blockade although muscle relaxants are almost always used for mask ventilation before tracheal intubation. Thus, this study was designed with a randomized parallel-group trial and compared the different timing of neuromuscular blockade under no significant difference in the anesthetic depth as shown by the sevoflurane concentration and bispectral index during mask ventilation. This study supports the previous findings that neuromuscular blockade increases tidal volume during mask ventilation.[18-20,31]

Atelectasis may develop after the induction of general anesthesia[37] and be aggravated by lower tidal volume.[38] In this study, the mean tidal volume

for 60 s of mask ventilation was 160 ml larger in the early rocuronium group than in the late rocuronium group. In addition, a larger minute volume of 1.3 L min^{-1} was observed in the early rocuronium group, which is about three times greater than the oxygen consumption of a healthy subject.[28] Therefore, the larger tidal volume and minute volume during mask ventilation might be beneficial to patients with high risk of atelectasis formation or low oxygen reserve, although these outcomes were not directly investigated.

The conventional practice of delaying neuromuscular blockade after checking mask ventilation seems to be based on the strategy to wake up the patient rapidly in unanticipated difficult mask ventilation.[3,4,15,16,23-25] However, this strategy may be impractical[4,9,11,15,16,23,26] because the duration of hypnotics is not short enough to restore the patient's spontaneous breathing without the risk of hypoxemia.[39] The relevant rescue for impossible mask ventilation is thus not to wait for the spontaneous breathing without any action but to place a tracheal tube or supraglottic airway as soon as possible with a minimum number of attempts.[1-6] The rescue intervention is more successful with adequate neuromuscular blockade than without blockade.[5-13] After detecting apnea, it was able to intubate the patient's trachea more rapidly in the early rocuronium group than in the late rocuronium group with no significant differences in intubation conditions and hemodynamic changes during laryngoscopy. Although it was not an emergency situation, these findings suggest that the early administration of rocuronium may provide optimal intubating conditions earlier than the late administration to rescue patients with unexpected difficult or impossible mask ventilation but successful

tracheal intubation.

As a secondary outcome, mask ventilation was graded using a four-point scale described in previous studies.[9,11,18,19,27,30,31] This can clinically classify easy and difficult mask ventilations[9,11,27,30] but be less sensitive in patients with normal airways.[18,19,31] This may explain why mask ventilation was graded as easy or moderate in all patients and was not significantly different between groups in this present study. Therefore, as the primary outcome, the expiratory tidal volume was measured to quantify the efficiency of mask ventilation as in previous studies.[19,20,31,33,34] Although manual ventilation is more common during anesthetic induction, pressure-controlled ventilation was provided to generate constant inflation pressure so that the tidal volume objectively reflects the efficiency of mask ventilation.[19,20,34] However, unlike a previous study using two hands for mask ventilation,[19] the one-hand technique was applied to simulate the real practice. In addition, the anesthesiologist who performed the mask ventilation was completely blinded to the treatment group in order to minimize performance bias.

When rocuronium is given intravenously in light anesthesia, it can cause a burning pain and withdrawal movements in the injection site because of its low pH.[29,40,41] The injection pain can be reduced by intravenous pretreatment of lidocaine 30 mg[40,41] as used in this study. This may explain no difference in response to the rocuronium injection between groups although rocuronium was given earlier with a lighter anesthetic state in the early rocuronium group. The patient may also complain of muscle weakness if rocuronium is given before complete loss of consciousness after the administration of propofol.

However, it was found that no patient recalled muscle weakness during anesthetic induction. This was probably because a high dose of propofol 2 mg kg^{-1}, used for rapid sequence induction[42], and a conventional dose of rocuronium 0.6 mg kg^{-1} were administered.

Although larger tidal volumes and earlier tracheal intubation were observed in the early rocuronium group, neuromuscular blockade before checking mask ventilation should be carefully considered depending on the clinical situation. It is appropriate to wait before delivering a neuromuscular blocker when the insertion of a supraglottic airway fails, or the upper airway examination or fiberoptic intubation are planned without muscle relaxation. On the other hand, difficult or impossible mask ventilation caused by laryngospasm can be best managed by neuromuscular blockade.[3]

This study has limitations. During anesthetic induction, the timing of neuromuscular blockade may be more important in patients with difficult airways, but these patients were excluded because of patient safety. The sample size of this study was also too small to compare adverse events between groups. In addition, the acceleromyograph was not calibrated in order to give rocuronium immediately after propofol without delay. However, the TOF count may be reliable without calibration because the four responses are amplified equally,[43] so it was unlikely to bias these findings. Also, the interval between injections of the first and second drugs was not measured, but it is only assumed that it would be similar to the difference of the time to tracheal intubation between groups.

In conclusion, larger tidal volumes during mask ventilation and earlier

tracheal intubation were shown in the early rocuronium group than in the late rocuronium group. Because the expiratory tidal volume can increase after neuromuscular blockade,[18-20,31] its evaluation before the blockade may lead to a wrong decision for the subsequent airway management. Adequate muscle relaxation is also required to optimize the conditions for tracheal intubation whether mask ventilation is possible or impossible.[5,6,9,11] Therefore, the administration of rocuronium before checking mask ventilation may be considered to provide larger tidal volumes and earlier tracheal intubation during induction of general anesthesia in patients with normal airways.

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요약 (국문 초록)

서론 : 전신마취 유도 도중 신경근차단제 투여가 마스크 환기 가능 여부를 확인할 때까지 지연되는 것은 흔한 일이나, 이러한 접근의 이점은 과학적으로 입증된 바가 없다. 따라서, 정상 기도를 가진 환자들에서 마스크 환기 확인 전후에 로큐로니움을 투여했을 때 마스크 환기 효율이 차이가 나는지 비교하였다.

방법 : 총 114 명의 환자들 중 58 명이 마스크 환기 확인 전 로큐로니움을 정주한 조기 투여군, 56 명이 확인 후 정주한 지연 투여군으로 무작위 배정되었다. 마스크 환기 동안 호기말 일회호흡량을 무호흡 후 10, 20, 30, 40, 50, 60 초 후 측정하였다. 또한, 마스크 환기의 용이함에 등급을 나누고 무호흡부터 기관 삽관까지의 시간을 측정하였다.

결과 : 무호흡 후 60 초 동안의 평균 일회호흡량은 로큐로니움 조기 투여군에서 지연 투여군보다 크게 나타났다[호흡당 552 (165) ml *vs* 393 (165) ml, 평균차 (95% 신뢰구간) 호흡당 160 ml (호흡당 98, 221 ml), $P < 0.001$, unpaired t-test]. 60 초 동안의 마스크 환기 동안 측정된 일회 호흡량에서 시간−군과의 상호작용이 유의하였기

때문에 (P < 0.001, 선형 혼합 효과 모델), 6 개 시점에서 짝비교를 수행하였다. 양 군의 일회호흡량 차이는 무호흡 후 10, 20, 30, 40 (P < 0.001 each, unpaired t-test), 50 초 (P = 0.002)에서 유의하였다. 기관 삽관까지의 시간은 로큐로니움 조기 투여군에서 지연 투여군보다 짧았다[116 (42) 초 *vs* 195 (41) 초, 평균차 (95% 신뢰구간) -79 초 (-96, -64 초), P < 0.001].

결론 : 정상 기도를 가진 환자들에서 마스크 환기 확인 전 로큐로니움을 투여한 군이 확인 후 투여한 군보다 큰 일회호흡량을 보였고, 기관 삽관도 더 빨랐다.

주요어 : 마스크 환기, 로큐로니움, 일회호흡량, 기관 삽관

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