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Original Contribution

Head position angles to open the upper airway differ less with the head positioned on a support☆,☆☆

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Abstract
Introduction: The aim of the study was to assess the effects of positioning the head on a support on "head position angles" to optimally open the upper airway during bag-valve mask ventilation.
Methods: We ventilated the lungs of anesthetized adults with a bag-valve mask and the head positioned with (n = 30) or without a support (n = 30). In both groups, head position angles and ventilation parameters were measured with the head positioned in (1) neutral position, (2) in a position deemed optimal for ventilation by the investigator, and (3) in maximal extension.
Results: Between groups ("head with/without a support") and between head positions within each group, head position angles and ventilation parameters differed ($P < .0001$, respectively). However, head position angles and ventilation parameters between head positions differed less "with a support" ($P < .001$), and ventilation parameters improved with a support compared with the head-without-a-support group ($P < .001$).
Conclusions: In the head-with-a-support group, when compared with the head-without-a-support group, head position angles differed less, indicating a decreased potential for failure during bag-valve mask ventilation with the head on a support. Moreover, in the head-with-a-support group, ventilation parameters differed less between head positions, and ventilation improved. These findings suggest a potential benefit of positioning the head on a support during bag-valve mask ventilation.

1. Introduction

Already 5 decades ago, Safar et al stated that a rescuer should extend the head and apply chin lift to optimally open the upper airway [1,2]. Furthermore, elevating the head by placing it on a support to achieve a "sniffing position" may

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be even more advantageous to keep the airway patent [3,4]. Since its first description in 1944, the sniffing position has been a commonly applied technique during anesthesia induction [5]. However, positioning the head on a support during cardiopulmonary resuscitation is not routinely used [6].

A prior study reported a wide range for "head position angles" with the head positioned flat on a surface [7], indicating a high potential for failure during bag-valve mask ventilation if the head is not positioned correctly. In addition, low efficiency with bag-valve mask ventilation in poorly skilled rescuers is underlined by prior studies [8]. Thus, defining an optimal head position angle for bag-valve mask ventilation may be an important step toward efficient and safe bag-valve mask ventilation. Therefore, we hypothesized that positioning the head on a support could improve bag-valve mask ventilation by reducing head position angles variability.

The primary end point of this study was to assess head position angles with the head elevated on a pillow ("head-with-a-support" position), similar to anesthesia induction position, and with the head flat on the surface without a pillow ("head-without-a-support" position), similar to the cardiopulmonary resuscitation position. To assess optimal lung ventilation in these positions, secondary end points were corresponding ventilation parameters. The null hypothesis was that optimal head position angles for facilitating bag-valve mask ventilation would not differ between the head-with-a-support and the head-without-a support positions.

2. Methods

2.1. Study design

This was a prospective, randomized, crossover study. The study protocol was approved by the local ethics committee.

2.2. Study population

Sixty patients, American Society of Anesthesiologists (ASA) grade 1-2, undergoing elective ophthalmologic or gynecologic surgery gave written, informed consent and were enrolled in the study. Exclusion criteria were a body mass index more than 35 kg/m^2; obvious congenital or acquired pathologies of the head, neck, or upper airway; peripheral nerve deficiencies; history of gastroesophageal reflux; or acute respiratory tract pathology.

2.3. Study protocol

Patients were premedicated with midazolam (7.5 mg orally) 30 minutes before induction of anesthesia. In the operating room, patients were placed in the supine position. A peripheral vein was cannulated, and routine standard noninvasive monitors were applied and activated. After preoxygenation, anesthesia was induced with remifentanil (2 μg/kg intravenously [IV]) and propofol (2-3 mg/kg IV). Neuromuscular block was achieved with rocuronium (0.6 mg/kg IV) to prevent spontaneous breathing and allow

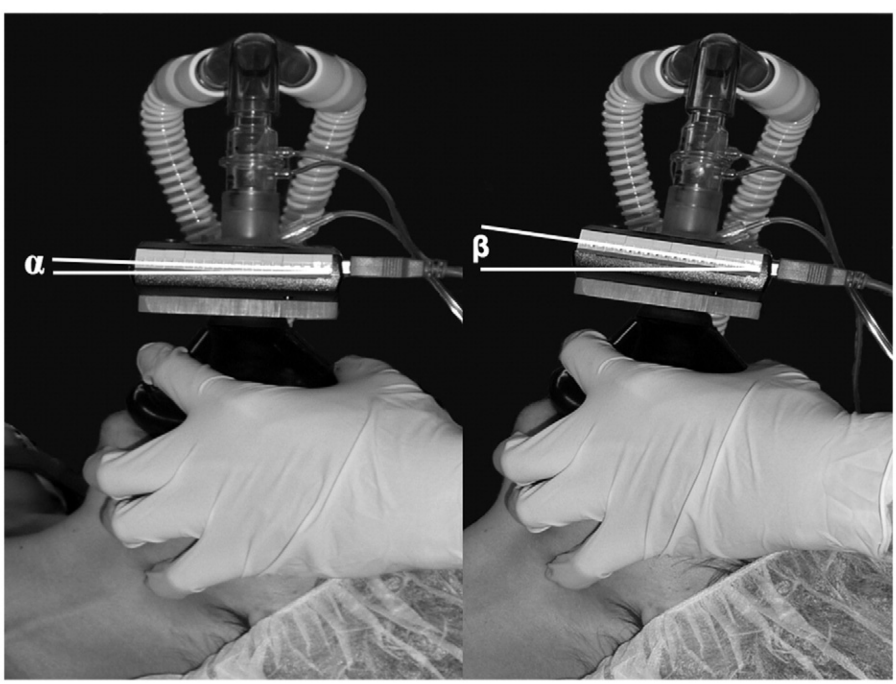

Fig. 1 Prototype of an electronic level attached to a ventilating mask. The electronic level is firmly attached between the face mask and the passive heat and moist exchanger. The head is on a support; neutral position (α) and extension (β) angles are marked.

maximal head motion, and measurements were made after the train-of-4 count was zero, indicating a complete neuromuscular block. Anesthesia was maintained with propofol (6-7 mg/kg per hour) and remifentanil (0.2-0.4 μg/kg per minute). A comfortably fitting bag-valve mask (Ambu, Ballerup, Denmark) was pressed gently on the patient's face, and chin lift was applied. An oral airway was not inserted. Mask ventilation was performed with pressure-controlled ventilation. For the head-with-a-support group, the head was positioned on a 7-cm-thick incompressible pillow (Fig. 1). To simulate typical routine mask ventilation during anesthesia, the ventilator settings in the head-with-a-support group were 15 cmH_2O peak airway pressure, 5 cmH_2O positive end-expiratory pressure, 15 breaths per minute, inspiratory flow 30 L/min, and inspiration:expiration ratio 1:2. In the head-without-a support group, however, we used 0 cmH_2O positive end-expiratory pressure to approximate self-inflating bag-mask ventilation during cardiopulmonary resuscitation and 10 cmH_2O peak airway pressure to achieve the same increment in positive pressure during ventilation. This difference in ventilator settings explicitly limits comparability of ventilation parameters between the head-with-a-support and the head-without-a-support groups. As in the head-with-a-support group, respiratory rate was 15 breaths per minute, inspiratory flow was 30 L/min, and inspiration:expiration ratio was 1:2 in the head-without-a-support group.

The head of each patient was placed in 3 different positions by 1 investigator (PP) with 9 years of anesthesia experience. The positions were as follows: (1) neutral position (no apparent flexion, torsion, or extension of the neck); (2) anesthetist's position, a position different from the other 2 positions that the investigator deemed optimal during manual ventilation. This was determined according to ease of ventilation (low resistance and high tidal volume) to assess the efficiency of ventilation in the range between neutral position and head extension; and (3) maximal extension with the head gently extended backwards as far as possible.

2.4. Measures

Primary outcome measures were head position angles, which were recorded for each of the 3 positions (neutral position, anesthetist's position, and maximal extension) in both groups (head with a support and head without a support). Head position angles were measured with a prototype electronic level (Fig. 1). This device was calibrated before assessing each patient and is able to measure angles with an accuracy of ±0.5°. The level was firmly attached between the heat and moist exchanger and the face mask (Fig. 1).

Secondary outcome measures were ventilation parameters, which were recorded for each position in both groups. Respiratory variables were analyzed with a pulmonary monitor (CP-100; Bicore Monitoring System, Irvine, CA) attached to a pneumotachograph (Varflex; Allied Health Products, Riverside, CA), which was connected to the patient's face mask (Fig. 1). Data collection continued for 1 minute for every head position.

2.5. Data analysis

Head position angles were used as the primary study end point for sample size calculation. Based on a previous study in awake volunteers [7] with measured mean head position angles of 21° for neutral position and 42° for extension and a common SD of 6°, we estimated a sample size of 10 patients to demonstrate statistical significance at a 2-sided α level of .05 with more than 0.95 power using the analysis of variance (ANOVA) procedure. However, to investigate differences in the secondary study end points for tidal volume, dynamic compliance, peak airway flow, and airway resistance, with magnitudes of effect likely being below the effect of angle differences, we included 30 patients in the head-with-a-support group and 30 in the head-without-a-support group.

Data are presented as mean (SD). The Kolmogorov-Smirnov test was used to assess normal distribution of parameters. Two-factorial ANOVA for repeated measurements was performed for the main analyses. Main effects included (1) differences between groups head with or without a support and (2) within-group differences according to head positions. A multiplicative interaction term for group differences (head with/without a support) by different levels of head positions was included in all ANOVA models (head with or without a support x head position). Response terms for the ANOVA analyses were head position angles as primary end points and ventilation parameters (tidal volume, peak airway flow, dynamic compliance, and airway resistance) as secondary end points. Post hoc tests were conducted as appropriate for those factors with more than 2 significant levels in the ANOVA. For categorical data, the χ^2 and Fisher exact tests were used, as appropriate. Two-sided $P < .05$ was considered statistically significant. All statistical analyses were performed using SAS 9.2 (SAS Institute, Inc, Cary, NC) and SPSS 18.0 (SPSS, Inc, Chicago, IL).

3. Results

Sixty patients were recruited. Patients' characteristics and vital parameter did not differ significantly between the head-with-a-support and the head-without-a-support groups (Table).

3.1. Head position angles

Regarding the primary end point head position angles, 2-factorial ANOVA indicated that head position angles differed between groups (head with/without a support) and between positions (neutral position, anesthetist's position, and extension) in each group ($P < .0001$; respectively). Moreover, head position angles differed less between the 3 head positions in the head-with-a-support group compared

Table Characteristics of patients with the head with a support vs without a support

	With a support	Without a support	P
	(n = 30)	(n = 30)	
Age (y)	39.9 ± 14.2	33.9 ± 11.2	.07
Sex, n (%)			1.0
Female	29 (96.7)	29 (96.7)	
Male	1 (3.3)	1 (3.3)	
ASA, n (%)			1.0
1	19 (63.3)	20 (66.7)	
2	11 (36.7)	10 (33.3)	
Body mass index	23.1 ± 3.5	23.1 ± 3.0	.94
Pulse (per min)	77.7 ± 16.9	75.1 ± 15.9	.55
Systolic blood pressure (mm Hg)	126.7 ± 17.2	119.0 ± 17.1	.09
Diastolic blood pressure (mm Hg)	75.5 ± 10.2	71.3 ± 12.7	.16
Spo_2 (%)	97.8 ± 1.3	97.8 ± 0.8	.81

Values are number (percentage) or mean ± SD.
ASA (classification of patients according to the American Society of Anesthesiologists).

with the head-without-a-support group (P = .001). This was confirmed by post hoc testing (Fig. 2).

3.2. Ventilation parameters

By analogy, regarding secondary end points (ventilation parameters), tidal volume, dynamic compliance, and airway resistance differed less and improved when positioning the patients' head with a support compared with those of the head-without-a-support group, which was confirmed by post hoc testing (Fig. 3).

4. Discussion

Head position angles and ventilation parameters differed less, and ventilation parameters improved in the head-with-a-support group compared with the head-without-a-support group.

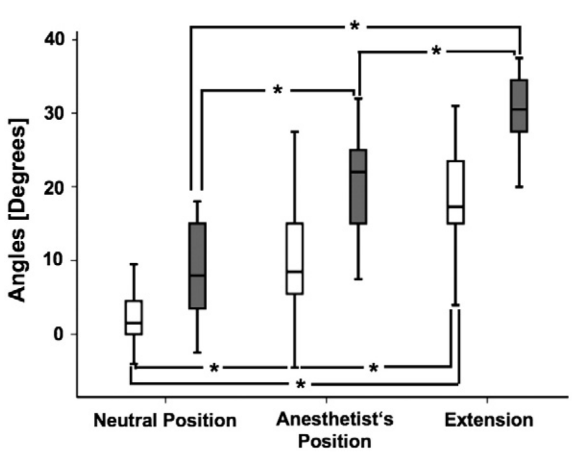

Fig. 2 Head position angles for head positioned on a support (white bars) and without a support (black bars); *P < .001.

In anesthetized patients, upper airway patency has been studied using x-ray [9], magnetic resonance imaging [10], flexible bronchoscopy [11], and direct video-assisted laryngoscopy [11]. However, none of these studies described angles to open the upper airway. We evaluated this model previously in anesthetized children [12]. Assessing head position angles and ventilation parameters during cardiopulmonary resuscitation would be desirable but is ethically not feasible. Thus, we believe that our experimental protocol for the head without a support is a close surrogate to study the upper airway in a typical preintubation cardiac arrest resuscitation scenario.

Interestingly, angles varied less in the head-with-a-support position than in the head-without-a-support position (Fig. 2). This may be because of reduced cervical spine motion capability when the head is placed on a support. A greater occipitoatlantoaxial extension with the head extended on a support as compared with no support may be causative for the diminished cervical spine motion capability [13]. Moreover, reduced cervical spine motion in the head-with-a-support group resulted in less difference in ventilation parameters when compared with the head-without-a-support group. This indicates a decreased potential for failure and a potential benefit especially for less skilled health care professionals. Although maximal extension appears to be the most efficacious position for ventilation with and without a support, ventilation quality was adequate in all head positions when the head was positioned on a support. In the head-without-a-support group, however, ventilation quality was insufficient in the neutral position as shown by low tidal volumes (Fig. 3).

The oral, pharyngeal, and tracheal axes are better aligned when positioning the head with a support [5], and in the operating theater, positioning the head with a support is extensively used to improve mask ventilation. During cardiopulmonary resuscitation, however, guidelines recommend positioning the head without a support, although this has not proven to result in better ventilation quality and outcome during cardiopulmonary resuscitation [14].

4.1. Limitations

First, head position angles were measured in anesthetized and paralyzed patients; thus, extrapolation of these findings to nonparalyzed patients may be limited. Second, we ventilated the lungs of the head-with-a-support group with a positive end-expiratory pressure of 5 cmH_2O, comparable with ventilation during anesthesia, and the lungs of the head-without-a-support group with a positive end-expiratory pressure of 0 cmH_2O, comparable with ventilation during cardiopulmonary resuscitation. Although both groups received the same increment of positive pressure to effect ventilation, the positive end-expiratory pressure in the head-

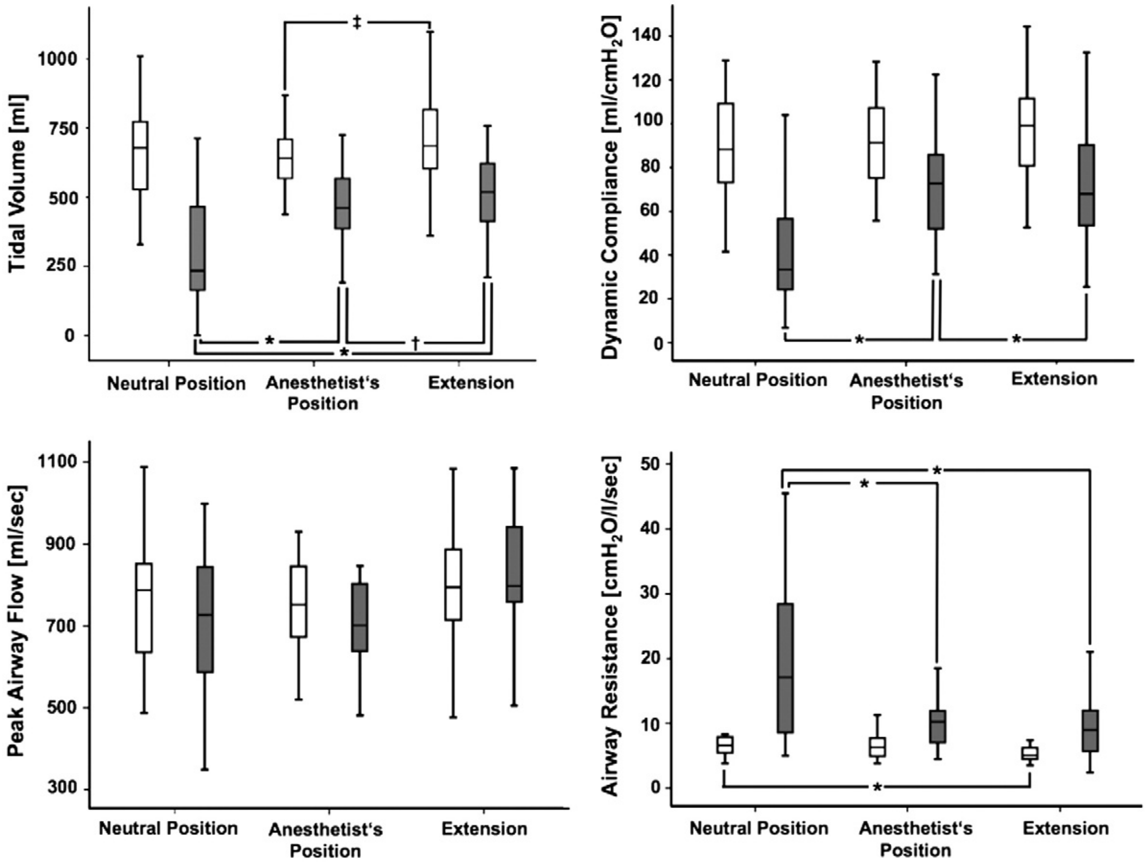

Fig. 3 Tidal volume, dynamic pulmonary compliance, peak airway flow, and airway resistance for different head position angles with the head with a support (white bars) and without a support (black bars); $*P < .001$; $^{\dagger}P < .01$; $^{\ddagger}P < .05$.

with-a-support group splints the pharyngeal wall, thus opening the upper airway [15]. However, this neither affects the main study end point head position angles nor the core message that head position angles differ less when using a support, indicating a lower potential for failure in face mask ventilation. However, comparability of ventilation parameters, which were the secondary study end points, between the 2 groups is limited. A further study is warranted to investigate ventilation efficiency in the head with a support and head without a support using the same pressure-controlled ventilation settings in both groups. Lastly, the anesthetist's position was defined subjectively by 1 investigator (PP) when manually bag-valve mask ventilating the patient and assessing ease of ventilation defined by high tidal volume and low resistance. Although this method is not highly academic, it is common clinical practice during bag-valve mask ventilation to assess ventilation efficiency.

5. Conclusions

In the head-with-a-support group when compared with the head-without-a-support group, head position angles differed less, indicating a decreased potential for failure during bag-valve mask ventilation with the head on a support. Moreover, in the head-with-a-support group, ventilation parameters differed less between head positions, and ventilation improved. These findings suggest a potential benefit of positioning the head on a support during bag-valve mask ventilation. Future studies should apply the same ventilator settings when comparing ventilation parameters with the head on and without a support.

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