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Özgün Araştırma / *Original Article*

Intraoperative Mechanical Ventilation Strategies in Newborns and Children in Turkey: A Survey Investigation

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Türkiye'de Yenidoğan ve Çocuklarda Intraoperatif Mekanik Ventilasyon Stratejileri: Anket Çalışması

ABSTRACT

Objective: *Most children under general anesthesia need mechanical ventilation (MV), but it has been reported in the literature that many parameters for this application are derived from adult patients. There is lack of literature about intraoperative MV for children. We conducted this survey to seek an answer for the question "How intraoperative respiratory parameters based on MV are managed for newborns and children among Turkish anesthesiologists?".*
Method: *A questionnaire containing 30 questions was sent to anesthesiologists. This survey collected information on clinical practice related to MV modes, tidal volume, positive end-expiratory pressure (PEEP), fraction of inspired oxygen (FiO_2), respiratory rate, monitoring of peripheral oxygen saturation (SpO_2) and end-tidal carbon dioxide ($EtCO_2$) and recruitment maneuvers (RMs).*
Results: *A total of 148 anesthesiologists and anesthesia residents responded to this survey. Of these respondents, 77% were working at a university hospital. More than 60% of respondents were using volume-controlled modes for newborns and children. The most commonly used tidal volume and PEEP values were 6-8 mL kg^{-1} and 3-4 cmH_2O, respectively. Monitorization, including SpO_2 and $EtCO_2$ was used by over 85% of respondents, while 75.7% of them were using recruitment maneuvers (RMs), which were often (55.4%) used during hypoxia with application of manual inspiratory pressure (71.6%).*
Conclusion: *The results of the present study indicate differences with the existing literature data. However, information about intraoperative application of mechanical ventilation in pediatric patients is limited, and there is a need for further study on this field.*

Keywords: *Survey, pediatrics, newborn, mechanical ventilation*

ÖZ

Amaç: *Genel anestezi altındaki çocukların çoğunun mekanik ventilasyona gereksinimi vardır. Ancak literatürde, bu uygulama için birçok parametrenin yetişkin hastalar örnek alınarak uygulandığı bildirilmiştir. Çocuklar için intraoperatif mekanik ventilasyon hakkında literatür eksikliği bulunmaktadır. Bu anketin amacı, Türk anesteziyologlar arasında, "Yenidoğan ve çocuklarda mekanik ventilasyona dayalı intraoperatif solunum parametreleri nasıl yönetilmektedir?" sorusuna yanıt aramaktır.*
Yöntem: *Anestezistlere yönelik 30 soru içeren anket uygulandı. Bu ankette mekanik ventilasyon modları, tidal volüm, pozitif son ekspiratuar basınç (PEEP), inspire edilen oksijen fraksiyonu (FiO_2), solunum sayısı, periferal oksijen saturasyonu (SpO_2), end-tidal karbondioksit ($EtCO_2$) ve recruitment manevraları ile ilgili klinik uygulamalar hakkında bilgi toplandı.*
Bulgular: *Bu ankete toplam 148 anestezi uzmanı ve anestezi asistanı yanıt verdi. Ankete katılanların %77'si üniversite hastanesinde çalışıyordu. Katılımcıların %60'ından fazlası yenidoğanlarda ve çocuklarda volüm kontrollü modu tercih etmekteydi. En sık kullanılan tidal volüm ve PEEP değerleri sırasıyla 6-8 mL kg^{-1} ve 3-4 cmH_2O idi. SpO_2 ve $EtCO_2$ içeren monitörizasyon %85'in üzerinde bir oranda uygulanmakta idi. Recruitment manevrasının kullanımı %75.7 idi. Bu teknik, sıklıkla (%55.4) hipoksi sırasında manuel inspiratuar basınç (%71.6) kullanılarak uygulanmakta idi.*
Sonuç: *Bu çalışmanın sonuçları mevcut literatürle farklılıklar göstermektedir. Bununla birlikte, pediyatrik hastalarda intraoperatif mekanik ventilasyon uygulamaları ile ilgili bilgiler sınırlıdır ve daha fazla çalışmaya gereksinim vardır.*

Anahtar kelimeler: *Anket, çocuk, yenidoğan, mekanik ventilasyon*

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INTRODUCTION

It should not be forgotten that "children are not small adults". In this context, there are differences in respiratory physiology between children and adults. Children's development occurs on the basis of these differences. In particular, there is a rapid growth in the first year of life. A reduction in airway resistance and an increase in lung compliance occur in parallel with the increasing weight of a child. Moreover, changes in their lung volumes and capacities continue throughout childhood [1].

Pediatric patients who receive general anesthesia in any surgical procedure or who need pulmonary support in an intensive care unit require invasive mechanical ventilation (MV). In general, the ventilation strategies applied to pediatric patients are inspired by relevant applications in adult patients. Nowadays, there is a limited number of studies related to intraoperative MV strategies in pediatric patients.

In many hospitals in Turkey, there are different intraoperative MV protocols for newborns and children, and there is no consensus about this issue. The aim of this study was to investigate the approaches of anesthesiologists to intraoperative MV strategies for newborns and children.

MATERIAL and METHODS

The study was approved by the local ethics committee of Çukurova University (2017/11). Survey data were collected using a web-based electronic platform. Before starting the study, survey questions were tested for intelligibility by 15 individuals who did not participate in the study. The survey was conducted via electronic data form available on the web. The questionnaire forms were sent to the e-mail addresses of registered anesthesiology specialists by TARD, and simultaneously, the authors re-informed anesthesiologists in nearby provinces. Only volunteers participated in the study. Participants responded to the survey questions in December 2017.

An online survey including 30 items was designed to gather information about intraoperative MV strategies for newborns and children under anesthesia. These items included 11 questions referring to descriptive information about respondents, while 8 questions were specific to newborns, and 11 questions were related to children. The questionnaire form is presented in Appendix 1.

Statistical analysis

Statistical analysis was performed using SPSS version 20.0 statistical software package (IBM SPSS Statistics for Windows, Version 20.0; IBM Corp., Armonk, New York, USA). The results were presented as frequency (%), and mean±standard deviation (and, if necessary, median, minimum and maximum).

RESULTS

A total of 148 anesthesiologists and anesthesia residents were included in the survey. Demographic data of respondents have been presented in Table I. The provinces where respondents worked were as follows: Adana (n=49, 33.1%), Istanbul (n=38, 25.7%), Gaziantep (n=15, 10.1%), Sanlıurfa (n=7, 4.7%), Ankara (n=6, 4.1%), Mersin (n=5, 3.4%,), Kahramanmaras

Table I. Respondents' characteristics

	n (%) median (min-max)
Gender (F/M)	77/71 (52/48)
Age (year)	
≤25	3 (2)
26-35	75 (50.7)
36-45	52 (35.1)
46-55	16 (10.8)
56-65	2 (1.4)
Position	
Anesthesia residents	65 (43.9)
Anesthesiologist	47 (31.8)
Anesthesiologist (Academician)	36 (24.3)
Anesthesia experience (years)	
Anesthesia residents	1 (0-5)
Anesthesiologist	6 (1-25)
Anesthesiologist (Academician)	10 (4-34)
Graduated	
University Hospital	115 (77.7)
Ministry of Health Education and Research Hospital	19 (12.8)
Ministry of Health / University Hospital	13 (8.8)
Other	1 (0.7)
Affiliation	
University hospital	78 (52.7)
Ministry of Health Education and Research Hospital	18 (12.2)
Ministry of Health / University Hospital	23 (15.5)
Public hospital	23 (15.5)
Other	6 (4.1)

Data are presented as number and percentage, and median (minimum and maximum).

Table II. Distribution of patients who received anesthesia within one year

	Median (min-max)
Newborn	10 (0-250)
Infant	40 (0-1500)
Pediatric	200 (0-2000)
Adult	700 (0-15000)

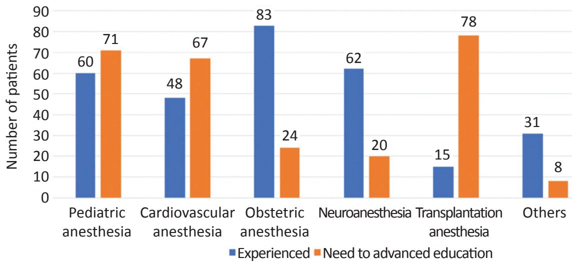

Figure 1. Experienced versus need to advanced education in branches

Table III. The usage of mechanical ventilation modes and parameters by respondents

	Newborn (n, %)	Pediatrics (n,%)
Mechanical ventilation		
Volume controlled	90 (60.0)	128 (86.5)
Pressure controlled	72 (48.6)	64 (43.2)
Pressure support	17 (11.5)	12 (8.2)
Spontaneous ventilation	14 (9.5)	12 (8.2)
Other	9 (6.1)	1 (0.7)
Tidal volume (mL kg^{-1})		
<6	20 (13.5)	9 (6.1)
6-8	76 (51.4)	92 (62.2)
9-10	59 (33.8)	45 (30.4)
>10	2 (1.4)	2 (1.4)
PEEP usage		
Yes/No	98/50	114/34
PEEP values		
1-2	26 (17.6)	12 (8.1)
3	46 (31.1)	39 (26.4)
4	22(14.9)	29 (19.6)
5	18 (12.2)	41 (27.7)
>5	1 (0.7)	3 (2.0)
FiO_2 (%)		
21-29	11 (7.4)	9 (6.1)
30-39	48 (32.4)	49 (33.1)
40-49	83 (56.1)	91 (61.5)
50-99	33 (22.3)	25 (16.9)
100	0 (0)	0 (0)
Only during hypoxia	74 (50.0)	68 (45.9)
Respiratory rate (breaths min^{-1})		
<30	22 (14.9)	
31-40	106 (71.6)	
41-50	19(12.8)	
Other	1 (0.7)	

Data are presented as number and percentage
PEEP: Positive end expiratory pressure
FiO_2: Fraction of inspired oxygen

Table IV. Monitorization and recruitment maneuver's data

	n (%)
SpO_2 monitoring usage	
Yes/No	139/9 (93.9/6.1)
$EtCO_2$ monitoring	
Important	143 (95.6)
Less important	2 (1.4)
No important	3 (2)
$EtCO_2$ monitoring usage	
Always	129 (87.2)
Rarely	17 (11.5)
Never	2 (1.4)
Recruitment maneuver usage	
Yes/No	112/36 (75.7/24.3)
The need of recruitment maneuver	
During hypoxia	82 (55.4)
Post-intubation	19 (12.8)
Before extubation	57 (38.5)
Other	
Abdominal surgery	2 (1.4)
Long-term operation	1 (0.7)
Requirement usage	
Manual inspiratory pressure	106 (71.6)
Positive end-expiratory pressure	36 (24.3)
Inspiratory pressure	16 (10.8)

Data are presented as number and percentage.
SpO_2: Peripheral oxygen saturation
$EtCO_2$: End-tidal carbon dioxide

(n=5, 3.4%), Izmir (n=4, 2.7%), Tokat (n=4, 2.7%), Antakya (n=3, 2.0%), Bursa (n=3, 2.0%), Konya (n=2, 1.3%), a Van (n=2, 1.3%), and Edirne (n=1, 0.7%), Samsun (n=1, 0.7%), Diyarbakır (n=1, 0.7%) Siirt (n=1, 0.7%), and Nigde (n=1, 0.7%).

Within a given year, respondents had applied anesthesia more frequently to adult patients rather than pediatric patients (Table II). Respondents expressed themselves as the most experienced in obstetric anesthesia and they indicated that they needed advanced education on transplantation, pediatric, and cardiovascular anesthesia (Figure 1). Within the last two years, respondents attended approximately 4 scientific meetings (0-20). At these meetings, 38.5% (n=57) of respondents stated that they participated in presentations related to pediatric anesthesia. In daily anesthesia practice, anesthesia was administered to pediatric patients mostly between 1 and 10 years of age.

Respondents' preferred MV modes with decreasing frequency were as follows: Their first preference was to use the volume-controlled mode (VCV) in newborns and pediatric patients (n=90, 60% and n=128,

Appendix 1. Survey questions

1. Age (years)
   a. ≤25 b.26-35 c.36-45 d.46-55 e.56-65 f.≥66
2. Gender
   a. Female b. Male
3. Position
   a. Assistant b. Specialist c. Academician
4. How many years are you an expert?
   ……………………years
5. Which institution did you complete your specialty training?
   a. University Hospital
   b. Ministry of Health Education and research Hospital
   c. Ministry of Heath/University Hospital
   d. Other
6. Which city/district are you currently working?
   ……………………
7. Which institution do you work?
   a. University Hospital
   b. Ministry of Health Education and research Hospital
   c. Ministry of Heath/University Hospital
   d. State hospital
   e. Private hospital
8. Which anesthesia divisions do you consider yourself more equipped?
   a. Pediatric anesthesia
   b. Thoracic and cardiovascular anesthesia
   c. Obstetric anesthesia
   d. Neurosurgical anesthesia
   e. Transplant anesthesia
   f. Other…………………..
9. Which anesthesia divisions would you like to receive further education? Please specify ………………………………………………………………………
10. Number of scientific meetings within the last 2 years ………………………………………………………
11. Have you participated in pediatric anesthesia sessions / courses in these scientific meetings?
    a. Yes
    b. No
12. How many newborns, infants and pediatric patients are you anesthetized per year? Fill in the following items in order.
    a. I give anesthesia to ……………. newborns in a year.
    b. I give anesthesia to ……………. infants in a year.
    c. I give anesthesia to ……………. pediatric patients in a year.
    d. I give anesthesia to ……………. adult patients in a year.
13. Which pediatric age range do you anesthetize most frequently in your daily work plan? You can choose more than one answer.
    a. 0-30 days b.1-12 months c.1-6 years d.7-10 years e. >10 years
14. Which of the mechanical ventilation modes do you use during the intraoperative period in the newborn? You can choose more than one answer.
    a. Volume controlled ventilation modes
    b. Pressure controlled ventilation modes
    c. Pressure supported ventilation
    d. Spontaneous ventilation
    e. Other…………………………
15. What is your preferred tidal volume in the newborn?
    a. <6 mL/kg
    b. 6-8 mL/kg
    c. 8-10 mL/kg
    d. >10 mL/kg
16. How many breaths/min do you set in the newborn?
    a. <30/min
    b. 30-40/min
    c. 40-50/min
    d. Other……………………
17. Do you apply positive end-expiratory pressure for mechanical ventilation in the newborn?
    a. Yes b. No
18. If your answer is yes, how do you set positive end-expiratory pressure?
    a. 1-2 mmHg
    b. 3 mmHg
    c. 4 mmHg
    d. 5 mmHg
    e. >5 mmHg
19. How do you adjust the inspired oxygen concentration in a term newborn during the intraoperative period?
    a. 21-29%
    b. 30-39%
    c. 40-49%
    d.50-99%
    e.100%
    f. When hypoxia develops, I only use 100% oxygen for a short time.

20. Which of the mechanical ventilation modes do you use during the intraoperative period in the pediatric patient? You can choose more than one answer.
    a. Volume controlled ventilation modes
    b. Pressure controlled ventilation modes
    c. Pressure supported ventilation
    d. Spontaneous ventilation
    e. Other…………………………
21. What is your preferred tidal volume in the pediatric patients?
    a. <6 mL/kg
    b. 6-8 mL/kg
    c. 8-10 mL/kg
    d. >10 mL/kg
22. Do you apply positive end-expiratory pressure for mechanical ventilation in the pediatric patients?
    a. Yes b. No
23. If your answer is yes, how do you set positive end-expiratory pressure?
    a. 1-2 mmHg
    b. 3 mmHg
    c. 4 mmHg
    d. 5 mmHg
    e. >5 mmHg
24. How do you adjust the inspired oxygen concentration in a term newborn during the intraoperative period?
    a. 21-29%
    b. 30-39%
    c. 40-49%
    d.50-99%
    e.100%
    f. When hypoxia develops, I only use 100% oxygen for a short time.
25. Do you the use continuously monitoring peripheral oxygen saturation in the intraoperative period?
    a. Yes b. No
26. Your opinion about the use of end-tidal CO2 monitoring in the intraoperative period:
    a. Important
    b. Less important
    c. Insignificant
27. How often do you use end-tidal CO2 monitoring in the intraoperative period?
    a. Continuous
    b. Sometimes
    c. No
28. Do you use recruitment maneuvers?
    a. Yes b. No
29. If your answer is yes, which cases do you apply “recruitment” maneuvers? You can choose more than one answer.
    a. In case of hypoxia
    b. After intubation
    c. Before extubation
    d. Other
30. If your answer is yes, how do you perform “recruitment” maneuvers?
    a. With manual inspiratory pressure application
    b. With PEEP application in mechanical ventilator
    c. With increased inspiratory pressure in the mechanical ventilator

86.5%, respectively). Their second preference was to use the pressure-controlled mode (PCV). In terms of tidal volume (Vt), most respondents (n=76, 51.4% for newborns and n=92, 62.2% for pediatric patients) reported that they applied 6-8 mL kg^{-1}. The reported use of positive end-expiratory pressure (PEEP) was 66% for newborns and 77% for pediatric patients. Generally, PEEP values used by participants were 3-4 cmH_2O for all age groups (Table III). During anesthesia, the adjusted fraction of inspired oxygen (FiO_2) and respiratory rate of neonates are shown in Table III.

For monitorization during anesthesia, 93.1% and 87.2% of respondents used peripheral oxygen saturation (SpO_2) and end-tidal carbon dioxide ($EtCO_2$), respectively. The rate of use of recruitment maneuvers (RMs) was 75.7% among respondents. Of all respondents, 55.4% mentioned that they used RMs during hypoxia, and these maneuvers were set with manual inspiratory pressure by 71.6% of respondents (Table IV).

DISCUSSION

This study showed that applications of MV for newborns and pediatric patients reflect varied approaches, and there is no clear consensus. We found that the rate of use of VCV was high and that Vt and PEEP levels were moderate in mechanically-ventilated neonates and pediatric patients under general anesthesia.

Although some studies have addressed respiratory management in pediatric anesthesia, there is no study related to intraoperative ventilation strategies in the literature. When compared with existing survey studies conducted in different countries, the lesser number and relatively younger respondents used intraoperative ventilation strategies in our study [2,3].

Most respondents stated that they were experienced in the field of obstetric anesthesia and reported that they mostly needed advanced education regarding transplantation, pediatric, and cardiovascular anesthesia. As a result of this survey, further meetings and trainings on pediatric anesthesia can be encouraging for Turkish anesthesiologists.

In pediatric anesthesia practice, PCV is the generally preferred ventilation mode [4]. However, our results showed that respondents used VCV modes more frequently than PCV mode for neonates and pediatric patients. It is possible that respondents' avoided PCV modes, as there is no volume guarantee due to the characteristics of the anesthesia machine used [4]. Similarly, in neonatal anesthesia practice, PCV is given more priority than VCV by pediatric anesthesiologists, because the ventilators of conventional anesthetic machines do not provide small tidal volumes (less than 20 mL). However, new generation anesthesia machines can provide adequate tidal volumes, and volume-targeted ventilation strategies decrease the risk of ventilator-induced lung injury [5]. We would like to state that there is still no evidence about which ventilation mode is superior in the operating room.

Available evidence suggests that the use of lung-protective ventilation (LPV) strategies is beneficial for adult patients, especially for those hospitalized in critical care units. Compatible with this opinion, Futier et al. [3] argued that LPV strategies that improved clinical outcomes after abdominal surgery could also be used during the intraoperative period for adult patients. Similarly, the importance of LPV is emphasized by neonatologists. Lung-protective ventilation strategies are based on the same parameters set for adult patients, including PEEP and limited Vt [6]. However, the limit for tidal volume of newborns and children is uncertain. Even though LPV is recommended for these patient groups, the majority of newborns and children that need to be anesthetized have no primarily pulmonary disease. In a recently published review, Kneyber [1] stated that lower Vt in pediatric patients is linked with higher mortality. Interestingly, in newborns, Abouzeid et al. [7] reported that the Vt of newborns under general anesthesia is highly variable. In the light of this information, although there is a lack of evidence about the optimal Vt for pediatric ventilation, a Vt ranging between 6, and 10 mL kg^{-1} is recommended [1]. The majority of respondents favored a Vt of 6-8 mL kg^{-1} as their first option and 9-10 mL kg^{-1} as their second option in both newborns and children, and these results were consistent with the literature.

Another subject to be discussed is PEEP application. In children under general anesthesia, the aim of using PEEP is to prevent decline in functional residual capacity (FRC), airway closure, and atelectasis [8]. A prospective study including 46 children without cardiopulmonary disease showed that a 6 cm H_2O PEEP was associated with positive effects on FRC and ventilation homogeneity at high levels of oxygen when compared with a 3 cmH_2O PEEP [9]. Another study indicated that 3 cmH_2O reversed the impact of neuromuscular blocking on FRC in infants and children who were anesthetized and paralyzed [10]. Although the level of PEEP may be adjusted by about 5 cmH_2O during intraoperative period based on the literature data , there are no guidelines about optimal PEEP levels for all pediatric ages [1]. In our study, Turkish anesthesiologists preferred to use 3-4 cmH_2O for PEEP as their first choice, and this result was consistent with the literature findings.

During anesthesia, FiO_2 is another ventilation parameter that should be considered. The results from our study indicated use of FiO_2 in the range of 30-50% for newborns and pediatric patients.

However, these values seemed high compared to the literature. A high FiO_2 has a negative impact on pulmonary mechanisms. The use of a high oxygen concentration increases pulmonary derecruitment and conceals ventilation - perfusion mismatch [8]. It is also responsible for the development of bronchopulmonary dysplasia and retinopathy of prematurity in preterm infants [11]. The proposed approach for infants and children involves the use of FiO_2 not exceeding 80% for a short period, such as anesthesia induction and recovery phase, reducing FiO_2 to 30-35% after stabilizing the airway and ventilation [12].

To maintain normocapnia, and mild hypercapnia in newborns, it is recommended that anesthesiologists should adjust respiratory rate to 30-60 breaths/min in ventilator settings. To evaluate FiO_2 and the levels of carbon dioxide, SpO_2 and capnography should be taken into account. $EtCO_2$ and SpO_2 are monitored to accomplish optimal ventilation. While waveform capnography informs us about the airway and ventilation changes of patients, monitoring of SpO_2 guides titration of FiO_2 so as to reach the target SpO_2 [1]. However, we think that SpO_2 and $EtCO_2$ monitoring are not given due attention by anesthesiologists [13,14].

Patients undergoing general anesthesia are potential candidates for atelectasis, and this results in an increase in postoperative complication rates [15]. The recommended method to avoid atelectasis and hypoxia is to apply RMs, which increase peak inspiratory pressure to 30 cmH_2O in children [14,16]. In our survey, RMs were used by most respondents. Recruitment maneuvers can be applied in different ways, such as increasing peak inspiratory pressure using a manual ventilation bag or the mechanical ventilator of anesthesia machine, for stepwise increase in only PEEP [13,15,17-19].

The main limitation of this study is the small number of participants. The number of participants may not be sufficient to reflect the whole country, but we believe that this study will be useful for giving an idea about MV strategies in children.

In conclusion, the results of our survey demonstrated that our first options in daily anesthesia practice do not seem to be compatible with the existing literature. We believe that the application of intraoperative MV has a great impact on newborns and children, and there are still shortcomings in the literature on this issue. In this regard, there is a need for further prospective studies related to MV in pediatric patients.

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