

# Application effect analysis of peak inspiratory pressure ( $P_{\text{peak}}$ ) combined with end-tidal carbon dioxide pressure ( $P_{\text{ET}}\text{CO}_2$ ) monitoring in the positioning of double-lumen bronchial tubes

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The lung isolation effect of double-lumen bronchial tubes (DLT) can provide a good surgical field for thoracoscopic surgery, ensure smooth procedure of the operation, ensure effective ventilation of the unaffected lung, and avoid the pollution of the secretion of the affected lung [1]. At present, DLT is still one of the most widely used important means of lung isolation in thoracic anaesthesia. The correct position of DLT directly affects the safety and effectiveness of lung isolation technology. Ensuring the correct position of DLT is a good way to maintain single-lung anaesthesia. On the premise of ventilation and oxygenation, the risk of hypoxaemia, airway damage, and poor lung collapse may occur when the DLT is in the wrong position. Lung auscultation and fiberoptic bronchoscopy (FOB) examination are the most common methods for localizing DLT. The traditional auscultation method has strong subjectivity, high blindness, low accuracy, and poor reliability [2]. The FOB inspection method is the most effective for DLT positioning, but there are certain limitations in the clinical use of FOB in primary hospitals due to its cost. At the same time, in thoracic surgery, the position of the DLT tube end often moves due to the placement position or surgical operation. Because FOB is expensive and cannot be used for continuous monitoring during surgery, it cannot be used to determine DLT displacement early [3].

The level of airway pressure is an important indicator of ventilatory resistance. Therefore, monitoring of airway pressure is often performed during mechanical ventilation. The airway pressure is generally controlled at 15–20 cm H<sub>2</sub>O during mechanical ventilation, and the airway pressure will increase when the two-lung ventilation (TLV) is changed to one-lung ventilation (OLV). When the TLV was changed to OLV, peak inspiratory pressure ( $P_{\text{peak}}$ ) increased by 67% when the DLT position was normal, and it increased by 74% when the DLT position was abnormal [4].  $P_{\text{peak}}$  is the maximum airway pressure during inhalation, which can reflect the position of the DLT to ensure the correct position of the DLT and the patency of the airway.  $P_{\text{peak}}$  can be maintained at a satisfactory level during OLV. Monitoring  $P_{\text{peak}}$  during OLV can help detect the abnormal position of DLT early, avoid the decrease of oxygen saturation (SPO<sub>2</sub>) and the occurrence of hypoxaemia, and then adjust the position of DLT, thereby preventing more serious consequences. End-tidal carbon dioxide pressure ( $P_{\text{ET}}\text{CO}_2$ ) refers to the concentration of CO<sub>2</sub> in the exhaled breath at the end of

the breath [5].  $P_{\text{ETCO}_2}$  is a non-invasive monitoring method that has become another vital sign monitoring indicator of the human body in addition to blood pressure, ECG, blood oxygen, body temperature, and blood pressure. In recent years, with the rapid development of sensing analysis and other technologies,  $P_{\text{ETCO}_2}$  monitoring has the advantages of being simple, available in real-time, and continuous and having high sensitivity.  $P_{\text{ETCO}_2}$  monitoring has been drawing more and more attention in various types of surgeries, critically ill patient rescue, and intensive care units [6].

At present, there is still a lack of quantitative indicators for judging the increase in airway pressure when the DLT is in the correct or in a misplaced position. This study was carried out to explore the feasibility of accurately locating the position of the DLT tube end through  $P_{\text{peak}}$  combined with  $P_{\text{ETCO}_2}$  monitoring. We assume that  $P_{\text{peak}}$  and  $P_{\text{ETCO}_2}$  can effectively predict the location of DLT, and that  $P_{\text{peak}}$  and  $P_{\text{ETCO}_2}$  in one-lung ventilation are higher than those in two-lung ventilation. The aim is to improve the accuracy of DLT tube end positioning and ensure the continuous and smooth progress of thoracic surgery without the aid of FOB positioning.

Before the operation, the Ethics Committee of our hospital gave consent and the patients and their families agreed and signed an informed consent form for anaesthesia. Sixty patients, aged 18–65 years, who needed thoracotomy under elective general anaesthesia, were randomly selected, with no history of bronchial asthma or airway hyperresponsiveness, and with cardiac function grade I–II. The patients were routinely fasted for 8 h and avoided drinking for 2 h before the operation. After entering the room, the venous access was routinely opened. Anaesthesia induction in patients was the same: midazolam 0.05 mg/kg, sufentanil 0.5  $\mu\text{g}/\text{kg}$ , propofol 1.0–2.0 mg/kg, and rocuronium 0.6 mg/kg [7, 8]. After 3 min, an appropriate type of DLT was selected, and the anaesthesia intubation operation was performed by an anaesthesiologist with the same amount of experience. In the experiment, intermittent positive pressure ventilation, tidal volume 8 ml/kg, frequency 12 times/min, inspiratory ratio 1 : 2, maintained  $P_{\text{ETCO}_2}$  35–40 mm Hg, inhaled 1.5–2.0% sevoflurane during the operation, and pumped remifentanyl and propofol were used to maintain an anaesthesia depth BIS of between 45 and 60 [9–11].

Monitoring of  $P_{\text{ETCO}_2}$  and  $P_{\text{peak}}$ . After induction, DLT was inserted, and the catheter position was adjusted until the auscultation was satisfactory, and the  $P_{\text{ETCO}_2}$ ,  $P_{\text{peak}}$  and  $\text{SPO}_2$  values of TLV and OLV were recorded. After turning over, the catheter position was adjusted and the auscultation was satisfactory, and the  $P_{\text{ETCO}_2}$ ,  $P_{\text{peak}}$  and  $\text{SPO}_2$

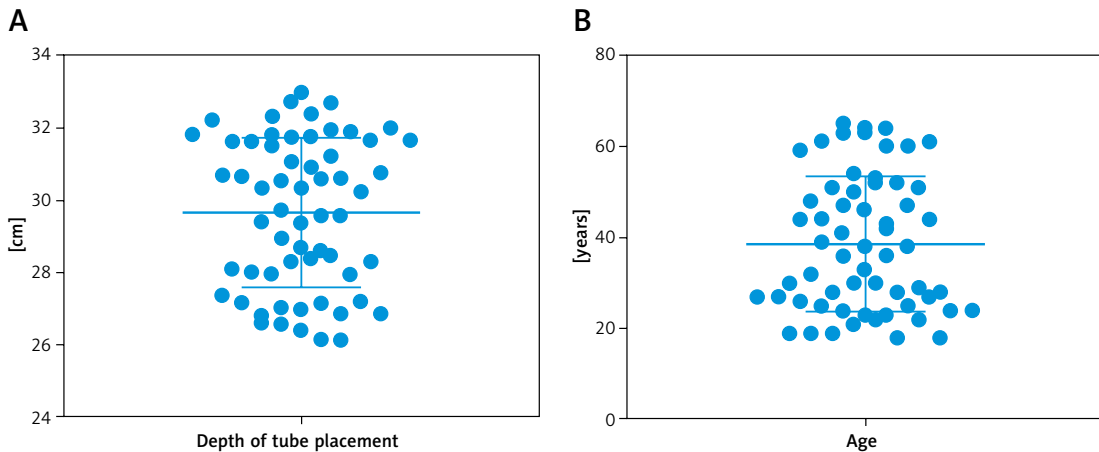
values were recorded after re-examination with FOB. Displacement of the catheter was defined as movement of the DLT by  $\geq 5$  mm from the correct position.

DLT positioning criteria. Judgment standard of auscultation: during TLV auscultation, the breath sounds of both lungs were the same as before intubation; during OLV auscultation, the breath sounds of each lobe on the ventilation side were the same as before intubation, but the breath sounds on the non-ventilation side disappeared.

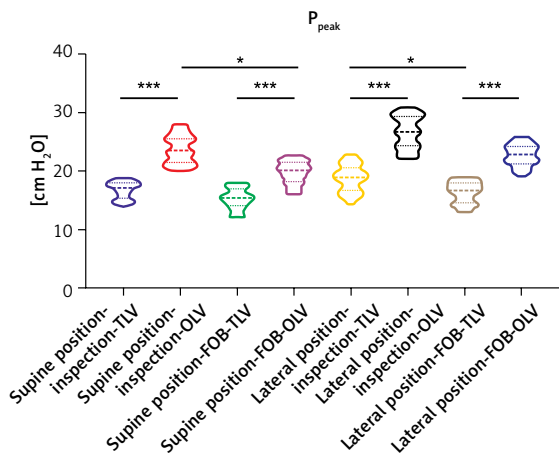
Criteria for FOB judgment: the positioning of the left DLT, the FOB is placed in the left tube, the left bronchus and the bronchial opening of the upper and lower lobes can be seen at the exit end of the tube, and the FOB is placed in the right tube, and the carina, the opening of the right bronchus and the left bronchus can be seen at the mouth of the tube. The inflated blue bladder is below the carina. The right DLT was positioned, and the FOB was inserted into the left tube. The carina, the left bronchial opening, and the inflated balloon in the right bronchus were visible at the tube orifice. The FOB was inserted into the right tube. The bronchial orifice of the right lower lobe, the bronchial opening of the right upper lobe can be seen through the lateral hole of the duct.

$P_{\text{ETCO}_2}$  criterion: TLV, the  $P_{\text{ETCO}_2}$  curve, and its values were normal. During OLV, the  $P_{text{ETCO}_2}$  curve and its value on the ventilating side were normal, and the  $P_{\text{ETCO}_2}$  curve on the non-ventilating side was a straight line, and its value was 0. Meeting this standard was considered satisfactory positioning. If there is a  $P_{\text{ETCO}_2}$  curve on the non-ventilation side but there is no expiratory plateau, the  $P_{\text{ETCO}_2}$  value is lower than normal, indicating that some lung isolation is incomplete; if the non-ventilation side  $\text{CO}_2$  curve shows an expiratory plateau, the  $P_{\text{ETCO}_2}$  value is in the normal range, indicating severe lung isolation.

General condition and depth of DLT insertion in patients. There were 60 patients, including 27 patients with left DLT and 33 patients with right DLT. DLT was successfully inserted in all patients at one time, and 8 cases were in place after repeated adjustment under auscultation. The mean intubation depth of the patients was  $29.66 \pm 0.27$  cm, and the mean age was  $38.62 \pm 1.90$  years (Figure 1). When the lung isolation effect of the supine auscultation method was satisfactory,  $P_{\text{ETCO}_2}$  monitoring showed that the lung isolation was incomplete in 16 cases. After FOB re-examination, 22 cases had improper position, of which 10 cases were inserted too deep, 8 cases were too shallow, and 4 cases had catheter distortion. The position of DLT changed in 9 cases by auscultation after turning over. The position of the catheter was adjusted until the lung isolation was satisfac-



**Figure 1.** Statistics of mean intubation depth (A) and mean age (B) of patients. A total of 60 patients, aged 18–65 years were involved in this test



**Figure 2.** The patient's  $P_{peak}$  test results. Detect the  $P_{peak}$  of the above 8 groups (Supine position-inspection-TLV, Supine position-inspection-OLV, Supine position-FOB-TLV, Supine position-FOB-OLV, Lateral position-inspection-TLV, Lateral position-inspection-OLV, Lateral position-FOB-TLV, and Lateral position-FOB-OLV). \* $P < 0.05$ , \*\*\* $P < 0.001$

tory, and  $P_{ET}CO_2$  was monitored. The lung isolation was incomplete in 9 cases, and shifted by FOB in 15 cases, of which 9 cases were too shallow and 6 cases were too deep.

Changes in  $P_{peak}$  during TLV and OLV. The OLV  $P_{peak}$  in the supine and lateral positions of the two detection methods was significantly higher than that of the TLV ( $p < 0.05$ ). The  $P_{peak}$  detected by the FOB method in the supine and lateral positions

was lower than that by the auscultation method, respectively ( $p < 0.05$ ). During OLV, 21 cases had  $P_{peak}$  below 25 cm H<sub>2</sub>O (1 cm H<sub>2</sub>O = 0.0981 kPa), 32 had  $P_{peak}$  at 25–30 cm H<sub>2</sub>O, and 7 had  $P_{peak}$  at 30–35 cm H<sub>2</sub>O. After FOB re-examination, there were 5 cases with  $P_{peak}$  at 25–30 cm H<sub>2</sub>O, and 55 cases with  $P_{peak} < 25$  cm H<sub>2</sub>O (Figure 2, Table I).

Changes in  $P_{ET}CO_2$  during TLV and OLV. The  $P_{ET}CO_2$  numerical monitoring results showed that in each group, the  $P_{ET}CO_2$  of OLV was higher than that of TLV. During TLV, the change of  $P_{ET}CO_2$  between auscultation method and FOB was not significant ( $p < 0.05$ ), while during OLV, the change of  $P_{ET}CO_2$  in the supine position was not obvious, and  $P_{ET}CO_2$  in the lateral position was significantly decreased after FOB review ( $p < 0.05$ ) (Figure 3 A, Table II).

Changes in  $SPO_2$  during TLV and OLV. Comparing FOB and auscultation, the content of  $SPO_2$  in OLV was significantly lower than that in TLV ( $p < 0.05$ ). After re-examination of FOB in supine and lateral positions, there was no significant difference in  $SPO_2$  between TLV and auscultation, but the  $SPO_2$  of OLV was significantly increased ( $p < 0.05$ ) (Figure 3 B, Table II).

The correct position of the DLT can ensure the effective implementation of the lung isolation technology in thoracic surgery. When the DLT is in the wrong position, there may be risks such as hypoxaemia, airway damage, and poor lung collapse. FOB examination is the most effective method for DLT positioning at present, but the clinical use of

**Table I.**  $P_{peak}$  (cm H<sub>2</sub>O) test results and results statistics of patients

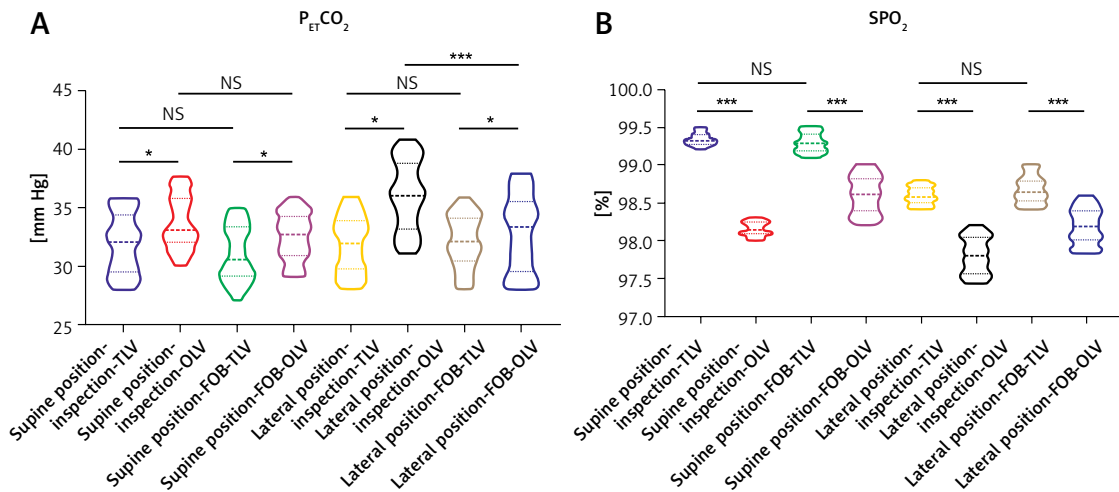
| $P_{peak}$ | Supine position |       |       |       | Lateral position |       |       |       |
|------------|-----------------|-------|-------|-------|------------------|-------|-------|-------|
|            | Inspection      |       | FOB   |       | Inspection       |       | FOB   |       |
|            | TLV             | OLV   | TLV   | OLV   | TLV              | OLV   | TLV   | OLV   |
| Mean       | 16.72           | 23.74 | 15.26 | 19.74 | 18.72            | 26.60 | 16.35 | 22.71 |
| SEM        | 0.18            | 0.31  | 0.22  | 0.25  | 0.30             | 0.36  | 0.24  | 0.23  |

FOB – fiberoptic bronchoscopy, TLV – two-lung ventilation, OLV – one-lung ventilation.

FOB in primary hospitals has certain limitations, and FOB examination cannot be used for continuous monitoring during surgery [12, 13]. Therefore, this study analysed the application of  $P_{peak}$  combined with  $P_{ETCO_2}$  monitoring in DLT localization.

For the DLT in the best position, the safe margin of movement is 16–19 mm for the left DLT and only 1–9 mm for the right DLT. Some studies believe that monitoring  $P_{ETCO_2}$  can more accurately judge the position of tracheal intubation and shorten the judgment time. During OLV, if there is air leakage from the ventilated side to the non-ventilated side, the  $P_{ETCO_2}$  curve and its value on the non-ventilated side can reflect the amount of leaked gas and the number of ventilations, i.e. it can reflect the DLT alignment and incomplete lung isolation [14–16]. In this study, when the lung isolation effect of the supine auscultation

method was satisfactory,  $P_{ETCO_2}$  monitoring showed that the lung isolation was incomplete in 16 cases. The position of DLT was changed in 9 cases by auscultation after turning over, and the position of the catheter was adjusted until the lung isolation was satisfactory, and  $P_{ETCO_2}$  was monitored, and the lung isolation was incomplete in 9 cases. This study shows that monitoring  $P_{ETCO_2}$  has significantly greater accuracy than auscultation in detecting incomplete lung isolation. Because the  $P_{ETCO_2}$  on the non-ventilated side is monitored, regardless of the position of the bronchial balloon (the depth of the DLT catheter), and as long as the side bronchus can be blocked, the  $P_{ETCO_2}$  cannot be monitored, but when the DLT is in the correct position, if the bronchial balloon fails to completely block the side bronchus, some airflow leaks into the non-ventilated side.



**Figure 3.** **A** –  $P_{ETCO_2}$  test results of patients. Detect the  $P_{ETCO_2}$  of the above 8 groups (Supine position-inspection-TLV, Supine position-inspection-OLV, Supine position-FOB-TLV, Supine position-FOB-OLV, Lateral position-inspection-TLV, Lateral position-inspection-OLV, Lateral position-FOB-TLV, and Lateral position-FOB-OLV). **B** –  $SPO_2$  test results of patients. Detect the  $SPO_2$  of the above 8 groups (Supine position-inspection-TLV, Supine position-inspection-OLV, Supine position-FOB-TLV, Supine position-FOB-OLV, Lateral position-inspection-TLV, Lateral position-inspection-OLV, Lateral position-FOB-TLV, and Lateral position-FOB-OLV). \* $P < 0.05$ , \*\*\* $P < 0.001$ , ns – not significant

**Table II.**  $P_{ETCO_2}$  (mm Hg) and  $SPO_2$  test results and results statistics of patients

| Parameter      | Supine position |       |       |       | Lateral position |       |       |       |
|----------------|-----------------|-------|-------|-------|------------------|-------|-------|-------|
|                | Inspection      |       | FOB   |       | Inspection       |       | FOB   |       |
|                | TLV             | OLV   | TLV   | OLV   | TLV              | OLV   | TLV   | OLV   |
| $P_{ETCO_2}$ : |                 |       |       |       |                  |       |       |       |
| Mean           | 31.93           | 33.71 | 31.05 | 32.53 | 31.91            | 36.05 | 32.12 | 32.84 |
| SEM            | 0.33            | 0.29  | 0.30  | 0.25  | 0.31             | 0.38  | 0.28  | 0.42  |
| Significant    | ac              | b     | c     | ab    | ac               | d     | ac    | ab    |
| $SPO_2$ (%):   |                 |       |       |       |                  |       |       |       |
| Mean           | 99.34           | 98.15 | 99.29 | 98.61 | 98.60            | 97.80 | 98.67 | 98.20 |
| SEM            | 0.01            | 0.01  | 0.02  | 0.03  | 0.01             | 0.03  | 0.02  | 0.03  |
| Significant    | a               | b     | a     | c     | c                | d     | c     | b     |

FOB – fiberoptic bronchoscopy, TLV – two-lung ventilation, OLV – one-lung ventilation.

The  $P_{ET}CO_2$  waveform can be measured on the non-ventilated side.

The level of airway pressure is an important indicator to reflect ventilation resistance. The airway pressure is generally 15–20 cm  $H_2O$  during TLV. When changing from TLV to OLV, the airway pressure will increase by 40% with the reduction of the effective lung ventilation area [17, 18]. The plateau pressure is the airway pressure at the end of inspiration, which overcomes the elastic pressure of the chest and lungs and keeps the lungs in a state of expansion.  $P_{peak}$  is the highest airway pressure when the lung is inflated. When it remains constant and the airway is unobstructed, the level of  $P_{peak}$  can accurately reflect the degree of airway obstruction, i.e. the level of  $P_{peak}$  is closely related to whether the DLT is in place. When the DLT is inserted too deeply and the left/right upper lobe bronchus is blocked, the left/right lung ventilation bronchus is reduced and the airway resistance is increased. The  $P_{peak}$  of OLV in the supine and lateral positions of the 2 detection methods was significantly higher than that of the TLV. The  $P_{peak}$  detected by the FOB method in the supine and lateral positions was lower than that by the auscultation method [19, 20]. In each group, the  $P_{ET}CO_2$  of OLV was higher than that of TLV. During TLV, the change of  $P_{ET}CO_2$  between auscultation method and FOB was not obvious, but during OLV, the change of  $P_{ET}CO_2$  in the supine position was not obvious, and the  $P_{ET}CO_2$  in the lateral position was significantly decreased after FOB review. Compared with the auscultation method, the  $SPO_2$  content of FOB in OLV was significantly lower than that in TLV. After the FOB review after the supine and lateral positions, there was no significant difference in  $SPO_2$  between TLV and auscultation, but the  $SPO_2$  of the OLV increased significantly.

Because the monitoring of  $P_{peak}$  and  $P_{ET}CO_2$  is continuous, slight changes in DLT during surgery can be detected in time, and its clinical placement rate is higher than that of auscultation. The use of  $P_{peak}$  and  $P_{ET}CO_2$  to evaluate the catheterization site of patients not only reduces the trauma of the clinical procedure, but also enables the clinician to dynamically monitor the changes of the patient's condition, which is critical for emergency treatment. Therefore, monitoring with  $P_{peak}$  and  $P_{ET}CO_2$  is a quick and easy way to improve DLT in place. The improvement of DLT positioning accuracy is conducive to the smooth progress of thoracic surgery, ensuring the safety of patients during surgery and rapid postoperative recovery, reducing the length of hospitalization, and reducing hospitalization costs. In this study, through the relationship between  $P_{peak}$  and  $P_{ET}CO_2$  monitoring and DLT tube end position, a simple, easy, accurate, and clinically practical DLT localization meth-

od was created. This method can be extended to grass-roots hospitals without FOB or with limited FOB, which is beneficial to the development of relevant departments in grass-roots hospitals. With the promotion of hierarchical diagnosis and treatment, we need to establish more diverse treatment systems and methods, and explore and compare the advantages of different methods to deal with different medical conditions and different patient groups. The limitations of this study are that the sample size is small and the follow-up work cannot be followed up in time. These factors need to be considered in future research.

In conclusion, compared with the auscultation method, the clinical delivery rate of  $P_{ET}CO_2$  and  $P_{peak}$  monitoring is higher, and the change of DLT position can be detected in time.

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Li Wang and Xianrong Hu contributed equally to this work.

### Conflict of interest

The authors declare no conflict of interest.

### References

- Moreault O, Couture EJ, Provencher S, Somma J, Lohser J, Ugalde PA, et al. Double-lumen endotracheal tubes and bronchial blockers exhibit similar lung collapse physiology during lung isolation. *Can J Anaesth* 2021; 68: 791-800.
- Huybrechts I, Tuna T, Szegedi LL. Lung separation in adult thoracic anesthesia. *Saudi J Anaesth* 2021; 15: 272-9.
- Cheng L, Liu S, Qi W, Dong Y. The incidence of tracheal bronchus in thoracic surgery patients and its implication for lung isolation: a retrospective cohort study. *J Cardiothorac Vasc Anesth* 2020; 34: 3068-72.
- Peng Z, Xia J, Yin N, Xue H. The effects of volume-controlled ventilation versus pressure-controlled ventilation on hemodynamic and respiratory parameters in patients undergoing lumbar spine fusion surgery: a randomized controlled trial. *Ann Palliat Med* 2021; 10: 9553-63.
- Zhang BJ, Tian HT, Li HO, Meng J. The effects of one-lung ventilation mode on lung function in elderly patients undergoing esophageal cancer surgery. *Medicine* 2018; 97: e9500.
- Yadav M, Reddy EP, Sharma A, Kulkarni DK, Gopinath R. The effect of position on PaCO<sub>2</sub> and PETCO<sub>2</sub> in patients undergoing cervical spine surgery in supine and prone position. *J Neurosurg Anesthesiol* 2017; 29: 298-303.
- Zhao K, Dong Y, Su G, et al. Effect of systemic lidocaine on postoperative early recovery quality in patients undergoing supratentorial tumor resection. *Drug Des Devel Ther* 2022; 16: 1171-81.
- Wang H, Xin W, Cui J. Experience of using a new brain surgery head frame and location sticker for treating spontaneous intracranial hematoma. *Front Neurol* 2022; 13: 818523.
- Sun Y, Feng H, Zou T, et al. Assessment of risk factors for postoperative cognitive dysfunction after coronary

- artery bypass surgery: a single-center retrospective cohort study. *Biosci Rep* 2021; 41: BSR20190719.
10. You X, Liu W. Evaluation of analgesia effect after ultrasound-guided laparoscopic renal surgery. *Comput Math Methods Med* 2021; 2021: 6194806.
  11. Yin K, Ding J, Wu Y, Peng M. Goal-directed fluid therapy based on noninvasive cardiac output monitor reduces postoperative complications in elderly patients after gastrointestinal surgery: a randomized controlled trial. *Pak J Med Sci* 2018; 34: 1320-5.
  12. Lazar A, Chatterjee D, Templeton TW. Error traps in pediatric one-lung ventilation. *Paediatr Anaesth* 2022; 32: 346-53.
  13. Lu Y, Xu D, Liu Z, et al. The use of bronchial blockers in patients with aberrant tracheobronchial anatomy: a case report. *Ann Transl Med* 2021; 9: 1268.
  14. Liu Z, Jia Q, Yang X. Awake intubation and extraluminal use of Uniblocker for one-lung ventilation in a patient with a large mediastinal mass a case report. *BMC Anesthesiol* 2020; 20: 125.
  15. Dan S, Yanping Y, Xu C, Jun Q. Ethnicity-stratified analysis of the association between P53 rs1042522 polymorphism and women HPV infection: a meta-analysis. *Microb Pathog* 2021; 161: 105099.
  16. Xiaochun J, Shuzhou Y, Youtao Z, Xu C. Association between TLR2 Arg677Trp polymorphism and tuberculosis susceptibility: a meta-analysis. *Microb Pathog* 2020; 144: 104173.
  17. Xiaochun J, Shuzhou Y, Youtao Z, Xu C. Quantitative assessment of the association between IL-10-592 A/C polymorphism and Kawasaki disease risk in Chinese population: evidence from a meta-analysis. *Cardiol Young* 2018; 28: 811-5.
  18. Xu C, Lingyan Q, Ping L, Wuning M. Cyfip1 is downregulated in acute lymphoblastic leukemia and may be a potential biomarker in acute lymphoblastic leukemia. *Tumour Biol* 2016; 37: 9285-8.
  19. Xu C, Min J, Ruike Z, Guohao G. Quantitative assessment of the association between ABC polymorphisms and osteosarcoma response: a meta-analysis. *Asian Pac J Cancer Prev* 2015; 16: 4659-64.
  20. Xu C, Ping L, Zheng Y, Wuning M. Expression of fragile histidine triad (FHIT) and WW-Domain Oxidoreductase Gene (WWOX) in nasopharyngeal carcinoma. *Asian Pac J Cancer Prev* 2013; 14: 165-71.