The clinical value of integrated pulmonary index monitoring during an endobronchial ultrasound-guided transbronchial needle aspiration procedure under sedoanalgesia

A prospective study

Hulya Y. Ak, *MD* ***Kubra Taskin,*** *MD,* ***Merve B. Yediyildiz,*** *MD,* ***Irem Durmus,*** *MD,* ***Gulten Arslan,*** *MD,* ***Sevda S. Comert,*** *MD,* ***Baris Sandal,*** *PhD,* ***Kemal T. Saracoglu,*** *MD.*

ABSTRACT

الأهداف: تقييم الأهمية السريرية لمراقبة المؤشر الرئوي المتكامل (IPI) أثناء شفط الإبرة عبر القصبة الهوائية (EBUS-TBNA) تحت التخدير وتحديد ما إذا كان يقلل من أحداث نقص الأكسجين مقارنة بالمراقبة القياسية.

المنهجية: تم تضمين خمسين مريضًا تتراوح أعمارهم بين 18-80 عامًا مع درجات الجمعية الأمريكية لأطباء التخدير من الدرجة الأولى إلى الثالثة، خضعوا لعملية الشفط بالإبرة عبر القصبة الهوائية - TBNA مع تخدير عميق لأغراض التشخيص. أجرينا قياس قيم مؤشر تخطيط كهربية الجسم في ست نقاط زمنية: خط الأساس، والتحريض، و 3 و 5 و 10 دقائق، وفي نهاية الإجراء. صُنّف المرضى بناءً على ما إذا كانت درجات مؤشر الضغط الداخلي المتكامل أعلى من 7 (المجموعة 1) أو أقل من 7 (المجموعة 2). أجريت هذه الدراسة المستقبلية القائمة على الملاحظة في مستشفى مدينة كارتال د. لطفي قيردار في الفترة من يوليو 2022 إلى يوليو 2023.

النتائج: أكمل 43 مريضًا الدراسة. كان معدل ثاني أكسيد الكربون في نهاية المد والجزر ومعدل التنفس في المجموعة 1 أعلى في نقاط زمنية متعددة، بما في ذلك الحث وبعد 3 و 5 و 10 دقائق من التخدير (p<0.05). وشهدت المجموعة 2 معدل أعلى من انقطاع النفس في هذه الأوقات (p<0.05). أظهر أولئك الذين حصلوا على درجات منخفضة في مؤشر IPI (على سبيل المثال، مؤشر IPI=3 و IPI=4) معدلات انقطاع النفس أعلى بكثير، في حين أن أولئك الذين حصلوا على درجات أعلى (على سبيل المثال، مؤشر IPI=7 و IPI=8) كانوا أقل عرضة لنوبات انقطاع النفس.

الخلاصة: أظهرت مراقبة مؤشر التنفس الاصطناعي أثناء إجراء تنظير القصبة تحت تأثير التخدير تحت تأثير التخدير تحسن الكشف عن نوبات انقطاع النفس وتعزيز سلامة الجهاز التنفسي مقارنة بتقنيات المراقبة القياسية. من الضروري إجراء أبحاث إضافية تشمل مجموعات سكانية أكثر تنوعاً لتأكيد هذه النتائج.

Objectives: To evaluate the clinical relevance of Integrated Pulmonary Index (IPI) monitoring during transbronchial needle aspiration (EBUS-TBNA) under sedation and determine whether it reduces hypoxic events compared to standard monitoring.

Methods: This prospective observational research was carried out at Dr. Lutfi Kirdar City Hospital, Istanbul, Turkey, between July 2022 and July 2023. A total of 50 patients, aged 18-80 years with American Society of Anesthesiologists scores of I-III, undergoing EBUS-TBNA with deep sedation for diagnostic purposes were included. The IPI values were measured at 6 time points: baseline, induction, 3, 5, 10 minutes, and at the end of the procedure. Patients were categorized based on whether their IPI scores were above 7 (group 1) or below 7 (group 2).

Results: A total of 43 patients completed the study. Group 1 had higher end-tidal carbon dioxide and respiratory rate at multiple time points, including induction and at 3, 5, and 10 minutes post-induction (p<0.05). Group 2 experienced a higher rate of apnea at these times (p<0.05). Those with lower IPI scores (namely, IPI=3 and IPI=4) showed significantly higher apnea rates, while those with higher scores (namely, IPI=7 and IPI=8) were less likely to have apneic episodes.

Conclusion: The IPI monitoring during EBUS-TBNA under sedation demonstrated improved detection of apnea episodes and enhanced respiratory safety compared to standard monitoring techniques. Additional research involving more varied populations is necessary to confirm these results.

Keywords: apnea, integrated pulmonary index, bronchoscopy, sedation

Saudi Med J 2024; Vol. 45 (11): 1223-1227
doi: 10.15537/smj.2024.45.11.20240621

From the Department of Anesthesiology and Reanimation (Ak, Taskin, Yediyildiz, Durmus, Arslan); from the Department of Thoracic Medicine (Comert), Dr. Lutfi Kirdar City Hospital, from the Department of Biostatistics (Sandal), Faculty of Medicine, Istanbul University-Cerrahpaşa, Istanbul, Turkey, and from the Department of Anaesthesiology, ICU, and Perioperative Medicine (Saracoglu), Hazm Mebaireek General Hospital, Doha, Qatar.

Received 24th July 2024. Accepted 17th October 2024.

Address correspondence and reprint request to: Dr. Hulya Y. Ak, Department of Anesthesiology and Reanimation, Dr. Lutfi Kirdar City Hospital, Istanbul, Turkey. E-mail: hulyayilmazak@gmail.com
ORCID ID: https://orcid.org/0000-0002-8682-6254

Endobronchial ultrasound-guided transbronchial needle aspiration (EBUS-TBNA) is a minimally invasive bronchoscopic procedure widely used for assessing mediastinal lymph nodes and masses.[1,2] However, there is no uniformity in the depth of sedation during EBUS-TBNA, leading to variability in sedation practices and medication choices across different medical centers.[3,4] Current sedation guidelines for procedures such as bronchoscopy recommend the standard monitoring of vital signs like heart rate, blood pressure, and partial oxygen saturation (SpO_2). Additionally, research has shown that incorporating capnography can help reduce hypoxic events (SpO_2<90% for over 15 seconds) and severe hypoxia (SpO_2<85%).[5,6] Hence, global guidelines suggest that capnography might offer added safety during deep sedation.[7]

The Integrated Pulmonary Index® (IPI) is an algorithm that provides a combined assessment of 4 parameters: heart rate, respiratory rate, SpO_2, and end-tidal carbon dioxide ($EtCO_2$). This index offers a simplified, single-value interpretation of the patient's respiratory status, facilitating continuous evaluation of ventilation and oxygenation during procedures.[8] The IPI score ranges from 1-10, with scores above 7 indicating stable respiratory parameters and those below 7 signaling the need for closer monitoring.

This study aimed to assess the effectiveness of IPI monitoring in patients sedated for EBUS-TBNA and to explore its potential in minimizing hypoxic events compared to traditional monitoring methods.

Methods. This prospective observational research was carried out at Dr. Lutfi Kirdar City Hospital, Istanbul, Turkey, between July 2022 and July 2023. The study included 50 patients of both genders, aged 18-80 years, with the American Society of Anesthesiologists (ASA) scores of I-III, who underwent EBUS-TBNA procedures under diagnostic moderate-to-deep sedation. Patients with significant cardiopulmonary comorbidities (namely, uncontrolled hypertension, chest pain, and advanced heart failure), ASA scores of IV or more, and those younger than 18 or older than 80 years were excluded from the study. Patients who discontinued the procedure, refused sedation, or experienced device malfunction were also excluded.

This study was carried out in line with the principles of the Declaration of Helsinki. Approval was granted by the ethics committee of Dr. Lutfi Kirdar City Hospital, Istanbul, Turkey (June 30, 2022/No: 2022/514/228/22).

After a preoperative anesthesia assessment, values from the monitoring of respiratory rate, IPI, SpO_2, heart rate, non-invasive blood pressure, and bispectral index (BIS) were collected. Values automatically recorded by the device were documented at the end of the procedure. Anesthesia induction was initiated with oxygen at 4 L/min, followed by administration of standard doses of anesthetic drugs to achieve moderate-to-deep sedation (midazolam 2 mg, propofol 1 mg/kg, and fentanyl 50 mcg). Intervention was carried out for hypoxic or severe hypoxic events, based on IPI values below 7 and SpO_2 evaluation (verbal stimulation and chin lift maneuver). The IPI values were measured at 6 different times: pre-procedure baseline, induction, 3 min after induction, 5 min after induction, 10 min after induction, and at the end of the procedure. For each measurement, group 1 had IPI values above 7 (low risk) and group 2 had IPI values below 7 (high risk).

During the procedure, at baseline and every 5 min thereafter, systolic blood pressure, heart rate, SpO_2, $EtCO_2$, IPI, and BIS values were recorded. Additionally, hypoxic (SpO_2<90% for >15 sec) and severe hypoxic events (SpO_2<85%) occurring during the procedure were documented. Other complications, such as hypotension, bleeding, and aspiration, were also recorded. Sedation depth was assessed using the observer assessment of alertness/sedation scale (OAA/S) and maintained at OAA/S level 3. Anesthesia depth was monitored using BIS, with values maintained between 60-80. An additional propofol dose (0.25 mg/kg) was administered if BIS values exceeded 80. Non-invasive blood pressure, heart rate, SpO_2, IPI, respiratory rate, $EtCO_2$, BIS, and OAA/S values were recorded at baseline, one min after induction, 3 min after induction, 5 min after induction, and at the end of the procedure. A modified Aldrete score (MAS) was determined at a post-procedure evaluation, with patients having MAS>9 sent to the post-anesthesia care unit (PACU).

Statistical analysis. The data were analyzed using The Statistical Package for the Social Sciences for Windows, version 29.0 (IBM Corp., Armonk, NY, USA). Descriptive measures such as frequency, percentage, mean, and standard deviation (SD) were computed. Data normality was assessed through the Shapiro-Wilk test. For the group comparisons, Fisher's exact test and Chi-square tests were employed for categorical variables, and independent sample t-tests and Mann-Whitney-U tests were used for continuous variables. A *p*-value of <0.05 was considered significant.

Disclosure. Authors have no conflict of interests, and the work was not supported or funded by any drug company.

Results. A total of 50 EBUS-TBNA patients were included in the study. Four patients were excluded from the study due to intolerance to the procedure (severe hypotension, hypoxia, and more), and 3 patients were excluded due to malfunction of the IPI device during the procedure. Thus, the study concluded with 43 patients. A total of 15 (34.9%) patients were female, and 28 (65.1%) were male. The mean age was 57.30±14.22 years, and the mean weight was 74.05±7.21 kg. Approximately 44.2% of the patients were smokers, and for the smokers, the mean smoking duration was 26.13±13.77 years. The mean procedure time was 19.47±2.74 minutes.

For each of the 6 measurement times, the groups were recreated using the same criteria and compared (Table 1). Group 1 had significantly higher $EtCO_2$ levels and respiratory rates than group 2 at baseline, induction, 3 min, 5 min, and 10 min ($p<0.05$). Mean arterial pressure (MAP) at induction was significantly elevated in group 1 ($p=0.002$). In contrast, the groups showed no meaningful differences at the other measured time points ($p>0.05$). Except for a significant increase in SpO_2 in group 1 at 10 min ($p=0.006$), SpO_2 was similar between the groups at all other times ($p>0.05$). The apnea rate was higher in group 2 at induction, 3 min, 5 min, and 10 min ($p<0.05$). There were no significant differences between groups in terms of the end-of-procedure $EtCO_2$, MAP, respiratory rate, and SpO_2 values ($p>0.05$). The need for additional anesthesia was higher in group 1 at 3 min ($p=0.009$), though no significant differences were noted at the other time points ($p>0.05$).

The results of Fisher's exact test ($p<0.001$) indicate a statistically significant association between IPI score and the presence of apnea. Individuals with lower IPI scores (namely, IPI=3 and IPI=4) had significantly higher rates of apnea, indicating a negative association between IPI and apnea, while those with higher IPI scores (namely, IPI=7 and IPI=8) were less likely to experience apnea (Figure 1).

Table 1 - Comparison of end-tidal carbon dioxide, respiratory rate, oxygen saturation, additional anesthetic requirement, and apnea rates between groups recorded at 6 different times.

Duration	Group 1 (IPI≥7)	Group 2 (IPI<7)	*P*-values
Baseline (n [Group1]=39, n [Group 2]=4)			
$EtCO_2$	32.95±4.92	20.00±3.37	0.001
MAP	99.26±12.31	95.25±16.52	0.430
RR	13.54±3.32	18.75±4.5	0.024
SpO_2	97.69±1.92	96.75±2.5	0.505
Induction (n [Group1]=19, n [Group 2]=24)			
$EtCO_2$	30.05±2.55	18.25±11.65	0.001
MAP	100.05±10.85	89.38±8.60	0.002
RR	13.79±3.57	8.96±5.52	0.001
SpO_2	95.47±7.57	95.58±3.12	0.079
Apnea			
Present	4 (21.1)	18 (75.0)	0.001
Absent	15 (78.9)	6 (25.0)	
3 minutes (n [Group1]=22, n [Group 2]=21)			
$EtCO_2$	33.09±5.02	25.62±9.29	0.003
MAP	92.36±7.91	93.14±10.50	0.874
RR	15.18±4.33	7.14±3.89	0.001
SpO_2	95.59±2.44	96.19±3.22	0.310
Additional anesthetic			
Present	7 (31.8)	0 (0.0)	0.009
Absent	15 (68.2)	21 (100)	
Apnea			
Present	4 (18.2)	8 (38.1)	0.185
Absent	18 (81.8)	13 (61.9)	
5 minutes (n [Group1]=22, n [Group 2]=21)			
$EtCO_2$	32.95±7.90	20.62±7.55	0.001
MAP	85.14±10.91	86.14±8.28	0.705
RR	14.91±3.64	8.10±5.92	0.001
SpO_2	97.05±1.99	94.62±4.21	0.094
Additional anesthetic			
Present	3 (13.6)	7 (33.3)	0.162
Absent	19 (86.4)	14 (66.7)	
Apnea			
Present	0 (0.0)	7 (33.3)	0.004
Absent	22 (100)	14 (66.7)	
10 minutes (n [Group1]=25, n [Group 2]=18)			
$EtCO_2$	33.44±4.98	25.22±8.08	0.002
MAP	94.52±11.77	102.28±15.23	0.080
RR	14.76±2.09	11.06±3.72	0.001
SpO_2	98.00±1.23	94.94±4.39	0.006
Additional anesthetic			
Present	4 (16.0)	7 (38.9)	0.156
Absent	21 (84.0)	11 (61.1)	
Apnea			
Present	0 (0.0)	6 (33.3)	0.003
Absent	25 (100)	12 (66.7)	

Values are presented as numbers and percentages (%) or mean ± standard deviation (SD). Group formations were reconstructed at each measurement time (6 times), with Group 1 being IPI:7 and above, and Group 2 being IPI below 7. IPI: integrated pulmonary index, $EtCO_2$: end-tidal carbon dioxide, MAP: mean arterial pressure, RR: respiratory rate, SpO_2: oxygen saturation

Discussion. For all measurements obtained after induction, the $EtCO_2$ values were significantly higher for patients with an IPI score of 7 or higher (group 1) than for those with an IPI score below 7 (group 2). Patients with lower IPI scores had significantly higher rates of apnea episodes compared to those with higher IPI scores.

In a large study involving 760 endoscopy patients across multiple medical centers, a significant decrease in desaturation and hypoxia was observed with the use of capnography (38.9% vs. 53.2%, $p<0.001$).[5] Additionally, a 10-year meta-analysis by Saunders et al[9] demonstrated an improvement from respiratory failure to apnea with the inclusion of capnography monitoring during procedural sedation and analgesia. Specifically,

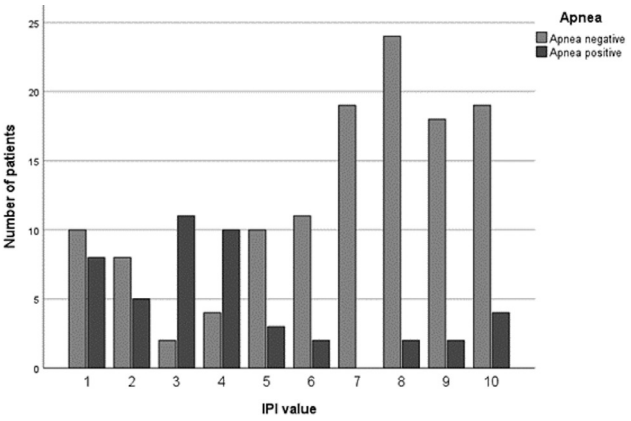

Figure 1 - Relationship between Integrated Pulmonary Index (IPI) value and apnea.

the use of capnography was associated with fewer cases of mild to moderate oxygen desaturation.[9] In a study by Peveling-Oberhag et al,[10] the use of capnography during sedation for percutaneous endoscopic gastrostomy (PEG) insertion was shown to detect the onset of mild and severe hypoxemia an average of 83-99 seconds earlier than standard monitoring. While this time frame may not be a concern for PEG patients, it represents a significant window for obtaining preventive measures for patients who experience rapid hypoxemia, such as pediatric patients or those undergoing EBUS-TBNA. The effect of capnography on respiratory safety has been demonstrated in various studies.[11] Our study used IPI score, calculated using 4 parameters crucial in respiratory observation: $EtCO_2$ measured with capnography, heart rate, SpO_2, and respiratory rate, alongside capnography-measured $EtCO_2$ to assess respiratory safety.

In a study carried out by Garah et al[12] on pediatric patients undergoing endoscopic procedures under sedation, they observed that IPI was more effective than standard monitoring in capturing all apnea and hypoxia episodes. The EBUS-TBNA procedures, similar to pediatric procedures, require quick detection of respiratory compromise, as hypoxic events can rapidly affect respiration. Therefore, early detection of hypoxic events is beneficial in this group.

Kuroe et al[13] used IPI to monitor elderly (≥75 years) or obese (body mass index of ≥28) patients in a PACU and at high risk of hypoventilation under general anesthesia. Their findings indicated that a low initial IPI score, along with fluctuations in IPI following admission to the PACU, was predictive of respiratory failure.[13] While studies on the use of IPI monitoring in patients at risk of hypoventilation, such as elderly patients, pediatric patients, or obese patients, exist in the literature, studies on the use of IPI monitoring in procedures where hypoxemia is commonly encountered, such as EBUS-TBNA, are very limited.[6,13,14] Hypoxemia during EBUS-TBNA is frequently encountered, even in patients without respiratory dysfunction before the procedure. The only study we found in the literature investigating the use of IPI in EBUS-TBNA patients is a retrospective study by Adıgüzel et al,[15] where they examined the effects of inhalational and intravenous magnesium use on IPI score and propofol consumption in EBUS-TBNA patients. However, in that study, IPI was used for all patients instead of standard monitoring.

Study limitations. Although the sample size in our study was adequate, expanding the sample may increase the robustness of the findings and improve the statistical power of the analysis. Patients with ASA score I-III were included. This limitation may not reflect the results in patients with higher ASA scores or significant comorbidities. Given these limitations, although our study demonstrates the superiority of IPI monitoring in detecting apnoea episodes and improving respiratory safety, further research in more diverse populations and clinical settings is needed to confirm these findings.

In conclusion, in our study, we compared standard monitoring with IPI monitoring during sedation for EBUS-TBNA, which is known for its rapid effect on respiratory parameters. This study demonstrated the superiority of IPI monitoring over standard monitoring in detecting apnea episodes and ensuring respiratory safety. However, it is important to note that these findings are based on a specific patient population undergoing EBUS-TBNA and may not be generalisable to all patient groups. The IPI monitoring may facilitate early intervention by the physician carrying out and monitoring the procedure in situations where respiration is compromised, but further research is needed to evaluate its effectiveness in different populations.

Acknowledgment. *The authors gratefully acknowledge CAN Translation and Editing Services for the English language editing.*

References

1. Aswanetmanee P, Limsuwat C, Kabach M, Alraiyes AH, Kheir F. The role of sedation in endobronchial ultrasound-guided transbronchial needle aspiration: systematic review. *Endosc Ultrasound* 2016; 5: 300-306.
2. Cases Viedma E, Andreo García F, Flandes Aldeyturriaga J, Reig Mezquida JP, Briones Gómez A, Vila Caral P, et al. Tolerance and safety of 5 models of sedation during endobronchial ultrasound. *Arch Bronconeumol* 2016; 52: 5-11.
3. Öztaş S, Aka Aktürk Ü, Alpay LA, Meydan B, Ogün H, Taylan M, et al. A comparison of propofol-midazolam and midazolam alone for sedation in endobronchial ultrasound-guided transbronchial needle aspiration: a retrospective cohort study. *Clin Respir J* 2017; 11: 935-941.

4. Sazak H, Tunç M, Alagöz A, Pehlivanoğlu P, Demirci NY, Alıcı İO, et al. Assessment of perianesthesic data in subjects undergoing endobronchial ultrasound-guided transbronchial needle aspiration. ***Respir Care*** 2015; 60: 567-576.
5. Beitz A, Riphaus A, Meining A, Kronshage T, Geist C, Wagenpfeil S, et al. Capnographic monitoring reduces the incidence of arterial oxygen desaturation and hypoxemia during propofol sedation for colonoscopy: a randomized, controlled study (ColoCap Study). ***Am J Gastroenterol*** 2012; 107: 1205-1212.
6. Gurlu R, Tolu Kendir O, Baspinar O, Erkek N. Can non-invasive capnography and integrated pulmonary index contribute to patient monitoring in the pediatric emergency department? ***Klin Padiatr*** 2022; 234: 26-32.
7. Riphaus A, Wehrmann T, Kronshage T, Geist C, Pox CP, Heringlake S, et al. Clinical value of the integrated pulmonary index® during sedation for interventional upper GI-endoscopy: a randomized, prospective tri-center study. ***Dig liver Dis Off J Ital Soc Gastroenterol Ital Assoc Study Liver*** 2017; 49: 45-49.
8. Michael FA, Peveling-Oberhag J, Herrmann E, Zeuzem S, Bojunga J, Friedrich-Rust M. Evaluation of the integrated pulmonary index® during non-anesthesiologist sedation for percutaneous endoscopic gastrostomy. ***J Clin Monit Comput*** 2021; 35: 1085-1092.
9. Saunders R, Struys MMRF, Pollock RF, Mestek M, Lightdale JR. Patient safety during procedural sedation using capnography monitoring: a systematic review and meta-analysis. ***BMJ Open*** 2017; 7: e013402.
10. Peveling-Oberhag J, Michael F, Tal A, Welsch C, Vermehren J, Farnik H, et al. Capnography monitoring of non-anesthesiologist provided sedation during percutaneous endoscopic gastrostomy placement: a prospective, controlled, randomized trial. ***J Gastroenterol Hepatol*** 2020; 35: 401-407.
11. Minami D, Murakami E, Shibata Y, Nakamura K, Kishino T, Takigawa N, et al. End-tidal capnographic monitoring during flexible bronchoscopy under fentanyl and midazolam sedation. ***Ann Palliat Med*** 2021; 10: 8665-8671.
12. Garah J, Adiv OE, Rosen I, Shaoul R. The value of integrated pulmonary index (IPI) monitoring during endoscopies in children. ***J Clin Monit Comput*** 2015; 29: 773-778.
13. Kuroe Y, Mihara Y, Okahara S, Ishii K, Kanazawa T, Morimatsu H. Integrated pulmonary index can predict respiratory compromise in high-risk patients in the post-anesthesia care unit: a prospective, observational study. ***BMC Anesthesiol*** 2021; 21: 123.
14. Yıldırım Ar A, Abitağaoğlu S, Turan G, Karip CŞ, Akgün N, Boybeyi DM, et al. Integrated pulmonary index (IPI) monitorization under sedation in cataract surgery with phacoemulsification technique. ***Int Ophthalmol*** 2019; 39: 1949-1954.
15. Adıgüzel ŞC, Akyurt D, Gullu Arslan N, Süren M. The effects of magnesium sulphate on integrated pulmonary index scores and propofol consumption during endobronchial ultrasonography: a retrospective study. ***Cureus*** 2023; 15: e44880.