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RESEARCH

Is there any correlation between integrated pulmonary index and thoracic surgery patients' follow-up data? a prospective, observational study

Entegre pulmoner indeks ile göğüs cerrahisi hasta takip verileri arasında ilişki var mı? prospektif, gözlemsel çalışma

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Abstract

Purpose: In this study, we investigated the relationship between integrated pulmonary index and patients' demographic data, surgical characteristics, postoperative complications, blood gas analysis, and hemodynamic values after thoracic surgery.
Materials and Methods: A total of 97 patients scheduled for elective thoracic surgery were included in this study. After surgery, integrated pulmonary index monitoring was performed for all patients in the post-anesthetic care unit. Patients' characteristics, postoperative hemodynamic values, arterial blood gas analysis, length of hospital stay, postoperative complications, duration of anesthesia, and duration of surgery were recorded. Their correlations with postoperative integrated pulmonary index scores at 30 minutes, 1 hour, and 2 hours were investigated.
Results: Patients' demographic data and surgical characteristics did not affect integrated pulmonary index scores. No significant correlation was found between integrated pulmonary index scores and duration of anesthesia, duration of surgery, postoperative complications, or length of hospital stay. However, there was a correlation between postoperative hemodynamic values, arterial blood gas analysis and integrated pulmonary index score.
Conclusion: Integrated pulmonary index monitoring is a bedside and non-invasive method that displays multiple parameters on a single screen, corraletes with arterial blood gas analysis and hemodynamic values. Therefore, it may provide advantages in early follow-up of thoracic surgery patients. However, multicenter, randomized controlled studies with a larger number of patients are needed to

Öz

Amaç: Bu çalışmada göğüs cerrahisi sonrası hastaların demografik verileri, cerrahi özellikleri, postoperatif komplikasyonları, kan gazı analizi ve hemodinamik değerleri ile entegre pulmoner indeks arasındaki ilişkiyi araştırdık.
Gereç ve Yöntem: Bu çalışmaya elektif göğüs cerrahisi planlanan toplam 97 hasta dahil edildi. Ameliyat sonrası anestezi sonrası bakım ünitesindeki tüm hastalara entegre pulmoner indeks monitörizasyonu uygulandı. Hastaların demografik özellikleri, postoperatif hemodinamik değerleri, arteriyel kan gazı analizleri, hastanede kalış süreleri, postoperatif komplikasyonlar, anestezi süreleri ve ameliyat süreleri kaydedildi. Bu değerlerin ameliyat sonrası 30. dakika, 1. saat ve 2. saat entegre pulmoner indeks skorları ile korelasyonları araştırıldı.
Bulgular: Hastaların demografik verileri ve cerrahi özelliklerinin entegre pulmoner indeks skorlarını etkilemediği görüldü. Entegre pulmoner indeks skorları ile anestezi süresi, ameliyat süresi, postoperatif komplikasyonlar veya hastanede kalış süresi arasında anlamlı bir ilişki bulunamadı. Ancak postoperatif hemodinamik değerler ile arteriyel kan gazı analizi ve entegre pulmoner indeks skoru arasında korelasyon mevcuttu).
Sonuç: Entegre pulmoner indeks monitorizasyonu, tek ekranda birden fazla parametreyi göstermesi, arteriyel kan gazı analizi ve hemodinamik değerleri ile korelasyon göstermesi, yatak başı ve non-invaziv bir yöntem olması nedeniyle göğüs cerrahisi hastalarının erken takibinde avantajlar sağlayabilir. Ancak entegre pulmoner indeksin göğüs cerrahisi geçiren hastalardaki etkinliğini araştırmak

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investigate the efficacy of integrated pulmonary index in patients undergoing thoracic surgery.
Keywords:. Blood gas analysis, hemodynamic values, integrated pulmonary index, monitoring, postoperative complications, thoracic surgery

için daha fazla sayıda hastayı içeren, çok merkezli, randomize kontrollü çalışmalara ihtiyaç vardır.
Anahtar kelimeler: Kan gazı analizi, hemodinamik değerler, entegre pulmoner indeks, monitörizasyon, postoperatif komplikasyonlar, göğüs cerrahisi

INTRODUCTION

The management of thoracic surgery patients could be complicated by postoperative complications (POCs) that can increase morbidity, mortality and health care costs. Complications can be due to chronic pulmonary diseases and reasons specific to the postoperative period. Therefore, continuous monitoring is important perioperative period. The most commonly used monitoring methods are capnography, arterial blood gas analysis, pulse oximetry, and respiratory rate. Although arterial blood gas analysis is the gold standard in the diagnosis of respiratory failure, its features, such as not giving instant results, being invasive, and not providing continuity, limit its use as an early warning method in postoperative follow-up[1].

Integrated pulmonary index (IPI) is a new monitoring method calculated using respiratory rate (RR), end-tidal carbon dioxide ($EtCO_2$), peripheral oxygen saturation (SpO_2), and heart rate (HR). It is designed to obtain information about patients' oxygenation and ventilation in the form of a single value or waveform from 1 to 10 with a mathematical algorithm using fuzzy logic (Table 1)[2]. When the IPI score is low, the following interventions should be applied: patient stimulation, chin lift and jaw thrust maneuvers, assisted mask ventilation, increasing the oxygen supply, and in case of necessity, endotracheal intubation. The most important advantages of IPI are that it is simple, easy to apply, non-invasive, and can provide continuous measurement. Although the IPI score is generally used by anesthesiology and intensive care specialists, it is also preferred for the follow-up of patients in the ward.

Until now, there is no study in the literature that has used the IPI score for early follow-up in patients undergoing thoracic surgery. The primary outcome of this study was to investigate the relationship between the IPI score and blood gas analysis, as well as hemodynamic variables. The secondary outcome was to investigate the correlation between patients' demographic data, POCs, surgical characteristics, and IPI score.

MATERIALS AND METHODS

This single center, prospective, observational clinical study was registered at ClinicalTrials.gov (NCT05368740). After faculty ethics committee approval (Cukurova University Faculty of Medicine, October 02, 2020, IRB no. 104/6) and written informed patient consent were obtained.

Sample

97 patients scheduled for elective thoracic surgery under general anesthesia between August 01, 2020 and January 31, 2021, were included in this study. Inclusion criteria were as following: American Society of Anesthesiologists (ASA) physical status I-III, the age between 18 and 75 years, and volunteer to participate study. Exclusion criteria were the presence of neuromuscular disorders, ASA>III, pneumonectomy surgery, morbid obesity with a body mass index (BMI)≥40, aged <18 years or >75 years, and pre-determined need for postoperative intensive care unit (ICU).

Procedure

After routine monitoring (electrocardiography, noninvasive arterial blood pressure, HR, and SpO_2), anesthesia induction was performed with intravenous (IV) 1.5-2 mg/kg propofol, 1 µgr/kg fentanyl and 0.6 mg/kg rocuronium. After adequate muscle relaxation, patients were intubated with an appropriately sized double-lumen tube, and $EtCO_2$ and body temperature were monitored. Anesthesia was maintained by 1.5-2% sevoflurane in oxygen and nitrous oxide mixture (50-50%) and repeated rocuronium doses if needed. One lung ventilation was started just before the thorax was opened. All surgeries were performed by same experienced surgical team. For postoperative analgesia, regional techniques were used if the patients consented, otherwise, IV opioids and nonsteroidal anti-inflammatory drugs (NSAIDs) were administered. At the end of the surgery, the neuromuscular blockade was antagonized with IV neostigmine (0.05 mg/kg) and atropine (0.015 mg/kg).

After extubation, the patients were followed up in the post-anesthetic care unit (PACU) and were monitored with the IPI (Capnostream-35 portable respiratory monitor, Medtronic, Minneapolis, USA) for 2 hours. The respiratory events requiring intervention are as follows: Apnea (absence of $ETCO_2$ waveform for 10 seconds or apnea episodes detected by clinical observation), bradypnea (respiratory rate<8 breaths/min for 2 min), $EtCO_2$>50 mmHg or <30 mmHg, tachypnea (respiratory rate>25/min), desaturation (SpO_2<90% for 10 seconds), and the IPI score level of ≤4. After 2 hours, the patients were transferred to the thoracic surgery ward once they fulfilled the standard PACU discharge criteria, which included being fully awake, maintaining stable hemodynamic and respiratory parameters, and expressing contentment with their analgesia.

Table 1. Integrated pulmonary index

Index range	Patient status
10	Normal
8–9	Within normal range
7	Close to normal range and requires attention
5-6	Requires attention and may require intervention
3-4	Requires intervention
1-2	Requires immediate intervention

The patients' demographic data including age, height, body weight, BMI, ASA physical status, comorbidities, and respiratory function test values were recorded. Additionally, the type and duration of surgery, as well as the duration of anesthesia were recorded. Postoperatively, blood pressure (systolic, diastolic, and mean arterial), SpO_2, IPI scores, and arterial blood gas analyses (evaluated with the ABL800 BASIC blood gas device, Radiometer, Denmark) were recorded at 30 minutes, 1 hour, and 2 hours, along with the length of hospital stay, need for ICU, and re-intubation. Finally, any postoperative complications (POCs) within 28 days were evaluated and recorded.

Statistical analysis

Categorical variables were expressed as numbers and percentages, whereas continuous variables were summarized as mean and standard deviation and minimum-maximum where appropriate. Repeated Measurements Analysis was applied to evaluate the change in the measurements obtained in the time interval. To evaluate the correlations between measurements, Pearson Correlation Coefficient or Spearman Rank Correlation Coefficient was used depending on whether the statistical hypotheses were fulfilled or not. All analyses were performed using IBM SPSS Statistics Version 20.0 statistical software package (IBM Corp. Released 2011, IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp). The statistical level of significance for all tests was considered to be 0.05.

RESULTS

A total of 97 patients were included in this study (Figure 1). Of these 40 were female (41.2%) and 57 were male (58.8%). The mean age of the patients was 50.26±16.30, and 53 patients (54.6%) had a history of smoking. Video-assisted thoracoscopic surgery (VATS) was the preferred surgical approach in 70.1% of cases, compared to thoracotomy. The most commonly observed POCs were atelectasis (15.5%) and drain leak (14.4%). Intravenous morphine was the most commonly used analgesic agent (84.5%) for postoperative pain management. None of the patients had an IPI score of <6 or required any interventions. It was observed that IPI scores increased over time in all patients, and none of the patients required ICU admission or re-intubation after surgery. Patients' demographic data and surgical characteristics are presented in Table 2.

Patients' demographic data, surgery characteristics and IPI scores: It was found that age, BMI, ASA score, smoking history, comorbidity, surgical approach, and POCs did not significantly affect the IPI scores (p>0.05) (Table 3). No significant correlation was found between the IPI scores and duration of anesthesia, duration of surgery, FEV1/FVC ratio, or length of hospital stay (p>0.05) (Table 4).

Patients' hemodynamic variables and IPI scores: There was a weak negative correlation between the IPI score at 30 minutes and SBP value at 30 minutes (p=0.030, r=-0.221), the IPI score at 2 hours and SBP values at 30 minutes and 1 hour (p=0.006, r=-0.275 and p=0.013, r=-0.251, respectively) (Table 5).

A weak negative correlation was also found between the IPI score at 30 minutes and DBP value at 2 hours (p=0.017, r=-0.242) (Table 5). In addition, there was a weak negative correlation between the IPI value at 2 hours and DBP in all time periods (p=0.046, r=-0.203 and p=0.009, r=-0.264 and p=0.026, r=-0.227, respectively) (Table 5). A weak negative correlation was found the IPI score at 2 hours and MAP at 30 minutes and 1 hour (p=0.029, r=-0.222 and p=0.020, r=-0.236, respectively) (Table 5). There were also weak negative correlations between the IPI score at 30 minutes and HR values at 30 minutes, 1 hour and 2 hours (p=0.002, r=-0.305 and p=0.006, r=-0.277 and p=0.051, r=-0.199, respectively) (Table 5). Patients' arterial blood gas analysis and IPI scores: A weak positive correlation was found between the IPI score at 30 minutes and pH value at 30 minutes (p=0.014, r=0.249), and the IPI score at 1 hour and pH value at 2 hours (p=0.053, r=0.197) (Table 6). In the majority of time periods, there was a correlation between the IPI scores and PaO_2 levels, as well as between the IPI scores and $PaCO_2$ levels (p<0.05) (Table 6). No correlation was found between the IPI scores and SpO_2, except at 30 minute (p>0.05) (Table 6)

Table 2. Patients' demographic data and surgical characteristics

Variable	Mean±SD (min-max) or number of patients (n)	Percent (%)
Age (year)	50.26 ± 16.30	-
Gender (male/female)	57/40	58.8/41.2
Height (cm)	167.00 ± 0.09	-
Weight (kg)	76.20 ± 14.61	-
Body mass index (kg/m²)	27.31 ± 5.07	-
ASA physical status (I/II/III)	30/47/20	30.9/48.5/20.6
Smoking (yes/no)	53/44	54.6/45.4
FEV1/FVC (%)	77.02±9.87	-
Comorbidity		
- No	20	20.6
- 1 comorbidity	42	43.3
- 2 comorbidity	24	24.7
- >3 comorbidity	11	11.4
Surgery approach		
- Thoracotomy (right/left)	29 (20/9.3)	29.9 (20.9/9.0)
- VATS (right/left)	68 (45/23)	70.1 (46.4/23.7)
Surgery type		
- Wedge resection	42	43.3
- Lobectomy	27	27.8
- Pleural/lymph node biopsy	23	23.7
- Thymectomy	5	5.2
Duration of anesthesia (min)	135.77±47.30 (60-270)	-
Duration of surgery (min)	113.20±44.52 (50-250)	-
Length of hospital stay (day)	5.60±4.50 (1-30)	-
POCs		
No	67	69.1
Yes	30	30.9
- Atelectasis	15	15.5
- Drain leak	14	14.4
- Pneumonia	1	1.0
- Others	5	5.0
IPI scores		
-30 minute	8.10±1.34 (6-10)	-
-1 hour	8.78±1.10 (7-10)	-
-2 hour	9.11±0.88 (7-10)	-

All values are presented as mean±SD (min-max) or number of patients (n) and percent (%). ASA: American society of anesthesiologists, FEV1: Forced expiratory volume in the first second, FVC: Forced vital capacity, IPI: Integrated pulmonary index, POCs: Postoperative complications, VATS: Video-assisted thoracoscopic surgery.

Table 3. Comparison between ASA score, age, surgical approach, POCs and IPI scores

	IPI 30 minute	IPI 1 hour	IPI 2 hour	p
Age (year)				0.536
-18-36 (n=24)	8.21±0.88	8.83±0.92	9.17±1.01	
-37-54 (n=24)	8.67±1.20	9.04±0.95	9.33±0.92	
-55-64 (n=26)	9.23±1.03	9.38±0.75	9.77±0.59	
- > 65 (n=23)	9.00±1.04	9.17±0.89	9.69±0.56	
BMI (kg/m²)				0.636
- < 18.5 (n=4)	8.00±0.82	8.75±0.96	9.25±0.96	
-18.6-24.9 (n=29)	8.55±1.21	8.83±1.00	9.38±0.90	
-25-29.9 (n=33)	8.82±1.04	9.06±0.83	9.51±0.71	
-30-34.9 (n=22)	9.00±1.11	9.50±0.74	9.64±0.85	
-35-39.9 (n=9)	9.22±0.83	9.44±0.73	9.55±0.88	
ASA physical status				0.619
-1 (n=30)	8.33±1.06	8.83±0.91	9.23±1.00	
-2 (n=47)	8.96±1.10	9.25±0.89	9.61±0.68	
-3 (n=20)	9.20±0.77	9.02±0.22	9.60±0.75	
Comorbidity				0.286
-No (n=20)	8.05±1.10	8.65±0.93	9.10±1.07	
-1 comorbidity (n=42)	8.93±0.92	9.26±0.83	9.57±0.70	
-2 comorbidity (n=24)	9.08±1.21	9.29±0.91	9.54±0.83	
->3 comorbidity (n=11)	8.91±1.04	9.00±0.77	9.82±0.40	
Smoking				0.262
-No (n=44)	8.66±1.20	9.16±0.89	9.45±0.90	
-Yes (n=53)	8.89±1.01	9.07±0.89	9.53±0.75	
Surgical approach				0.412
-Thoracotomy (n=29)	8.62±1.05	8.79±0.77	9.34±0.90	
-VATS (n=68)	8.85±1.12	9.25±0.90	9.56±0.78	
Pathology				0.880
-Malign (n=55)	8.78±1.15	9.09±0.12	9.51±0.11	
-Non-malign (n=42)	8.79±1.17	9.14±0.14	9.48±0.13	
POCs				0.648
-Yes (n=30)	8.43±0.82	8.80±0.71	9.26±0.83	
-No (n=67)	8.94±1.18	9.25±0.93	9.59±0.80	

All values are presented as mean±SD. ASA: American society of anesthesiologists, BMI: Body mass index, IPI: Integrated pulmonary index, POCs: Postoperative complications.

Table 4. Correlation between duration of anesthesia, duration of surgery, FEV1/FVC, length of hospital stay, and IPI scores

		IPI 30 minute	IPI 1 hour	IPI 2 hour
Duration of anesthesia	p	0.967	0.517	0.492
	r	0.004	-0.067	-0.071
Duration of surgery	p	0.776	0.489	0.590
	r	-0.029	-0.071	-0.055
FEV1/FVC	p	0.498	0.359	0.560
	r	-0.070	0.094	-0.060
Length of hospital stay	p	0.266	0.077	0.888
	r	-0.114	-0.181	-0.015

IPI: Integrated pulmonary index, FEV1: Forced expiratory volume in 1 second, FVC: Forced vital capacity.

Table 5. Correlation between postoperative hemodynamic values and IPI scores

			IPI 30 minute	IPI 1 hour	IPI 2 hour
SBP	30 minute	p	**0.030***	0.070	**0.006***
		r	**-0.221**	-0.185	**-0.275**
	1 hour	p	0.247	0.218	**0.013***
		r	-0.119	-0.126	**-0.251**
	2 hour	p	0.239	0.262	0.058
		r	-0.121	-0.115	-0.193
DBP	30 minute	p	0.100	0.245	**0.046***
		r	-0.168	-0.119	**-0.203**
	1 hour	p	0.208	0.269	**0.009***
		r	-0.129	-0.113	**-0.264**
	2 hour	p	**0.017***	0.261	**0.026***
		r	**-0.242**	-0.115	**-0.227**
MAP	30 minute	p	0.547	0.410	**0.029***
		r	-0.062	-0.085	**-0.222**
	1 hour	p	0.636	0.151	**0.020***
		r	-0.049	-0.147	**-0.236**
	2 hour	p	0.330	0.378	0.110
		r	-0.100	-0.091	-0.163
HR	30 minute	p	**0.002***	0.123	0.815
		r	**-0.305**	-0.158	-0.024
	1 hour	p	**0.006***	0.155	0.930
		r	**-0.277**	-0.146	0.009
	2 hour	p	**0.051***	0.686	0.597
		r	**-0.199**	-0.042	0.054

*p<0.05, nonparametric correlation analysis. IPI: Integrated pulmonary index, DBP: Diastolic blood pressure, HR: Heart rate, SBP: Systolic blood pressure, MAP: Mean arterial pressure.

Table 6. Correlation between postoperative blood gas analysis and IPI scores

			IPI 30 minute	IPI 1 hour	IPI 2 hour
pH	30 minute	p	0.014*	0.107	0.462
		r	0.249	0.165	0.076
	1 hour	p	0.077	0.073	0.210
		r	0.180	0.183	0.128
	2 hour	p	0.142	0.053*	0.160
		r	0.150	0.197	0.144
PaO_2	30 minute	p	0.323	0.004*	0.023*
		r	-0.101	-0.288	-0.231
	1 hour	p	0.001*	0.002*	0.027*
		r	-0.332	-0.312	-0.225
	2 hour	p	0.022*	0.269	0.190
		r	-0.233	-0.113	-0.134
$PaCO_2$	30 minute	p	0.009*	0.017*	0.002*
		r	-0.265	-0.241	-0.314
	1 hour	p	0.005*	0.021	0.010*
		r	-0.284	-0.234	-0.262
	2 hour	p	0.057	0.011	0.001*
		r	-0.194	-0.256	-0.333
SpO_2	30 minute	p	0.017*	0.518	0.296
		r	0.241	-0.066	-0.107
	1 hour	p	0.826	0.543	0.298
		r	-0.023	-0.063	-0.107
	2 hour	p	0.435	0.901	0.549
		r	-0.080	0.013	-0.062

*p<0.05, nonparametric correlation analysis. IPI: Integrated pulmonary index.

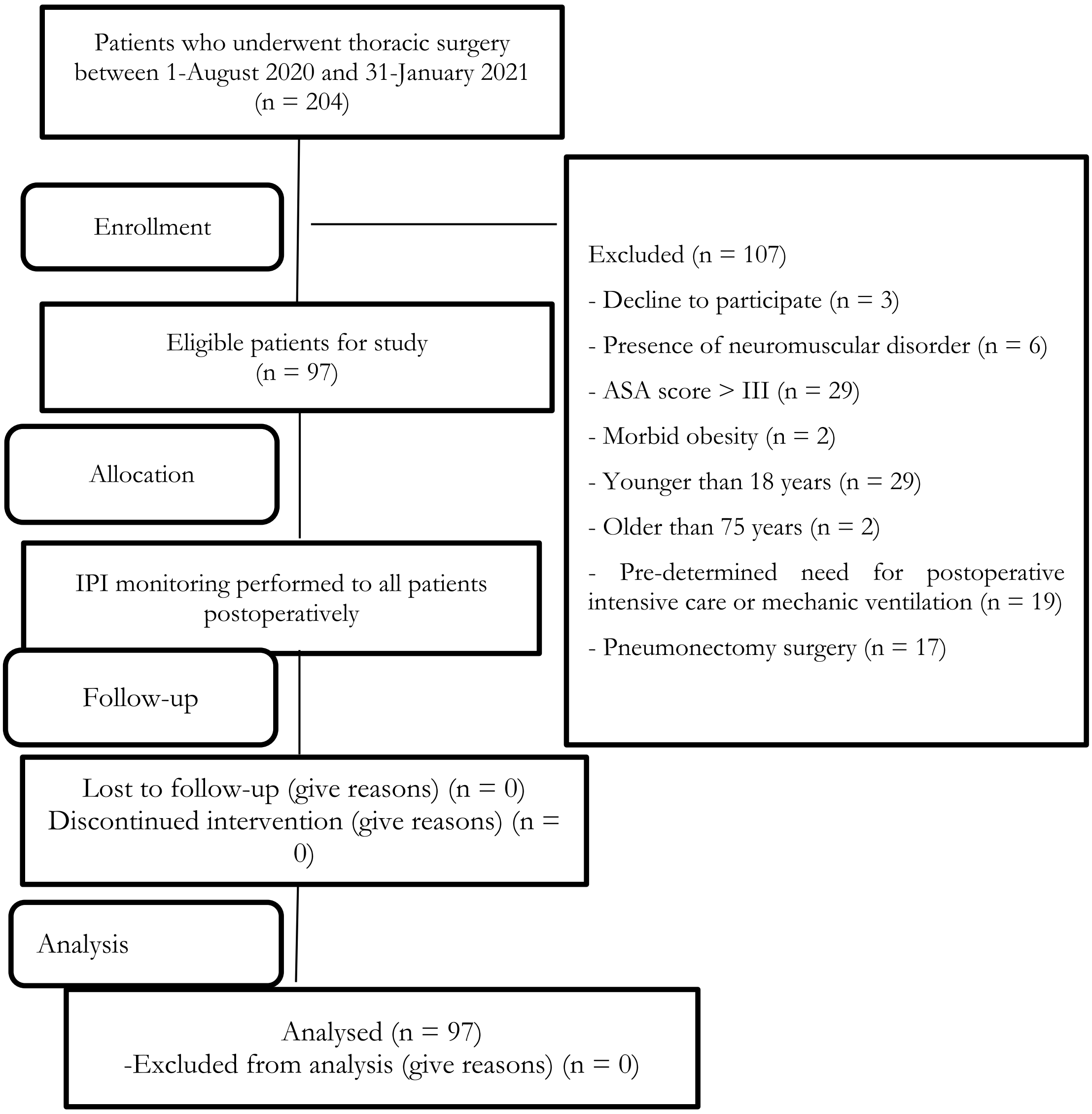

Figure 1. Flow chart of the study

DISCUSSION

This clinical study revealed correlations between the IPI scores and hemodynamic values, as well as between the IPI scores and arterial blood gas analysis during certain study periods among postoperative thoracic surgery patients. However, the IPI scores were not affected by the patients' demographic data and surgical characteristics. Similar to other surgeries, advanced age, comorbidity, higher ASA physical status, smoking, impaired pulmonary function, and higher BMI are associated with increased adverse respiratory events, mortality and morbidity in thoracic surgery patients[3]. The positive effects of VATS on postoperative pulmonary function and the length of hospital stay have been demonstrated in meta-analysis and several studies[4-6]. Due to the positive effect of VATS on respiratory function, we expected that the IPI scores would be higher in patients who underwent VATS compared to those who underwent thoracotomy. In addition, we thought that the parameters used in the calculation of the IPI score (RR, $EtCO_2$, SpO_2, and HR) may be affected by the demographic data of the patients. However, we could not find statistically significant correlations between the IPI score and surgical approach (thoracotomy versus VATS) or between the IPI score and patients' characteristics.

Respiratory failure, atelectasis, hematoma, pulmonary edema, persistent air leak, bronchopleural fistula, cardiac arrhythmia, and chylothorax are among the complications after thoracic surgery. One of these complications is postoperative extubation failure, which can arise from several factors such as impaired respiratory tract, ineffective cough, residual muscle relaxant effect, increased pulmonary secretions, and neuromuscular abnormalities[7]. It was found that the IPI score 1 hour after extubation was statistically lower in patients with extubation failure than those with successful extubation[8]. In a retrospective cross-sectional study, a decreasing IPI score within the 1 hour after extubation was also a stronger predictor of extubation failure than the other weaning variables[9]. Our results are consistent with this literature knowledge that early postoperative IPI values can predict the extubation failure. In our study, all patients were evaluated with the IPI for 2 hours in the PACU, none of them had < 6 IPI score, and consequently none of them required re-intubation, and IPI score increased over the time.

Decreased IPI scores after extubation could also predict POCs in patients undergoing elective off-pump coronary artery bypass surgery[1]. Another study, which evaluated only high-risk patients, showed that a low baseline IPI score and fluctuations in IPI scores after admission to the PACU predict respiratory failure[10]. It was demonstrated that IPI monitoring is superior to pulse oximetry for detecting apnea and hypopnea episodes in children during endoscopies[11]. During cataract surgery, IPI monitoring is also used to identify respiratory complications in sedated patients[12]. Moreover, in another study, a relationship between low IPI scores and respiratory complications (hypoxemia, airway narrowing, apnea, hypercapnia, wheezing etc) was found in high risk patients undergoing elective surgery[10]. Unlike our study, they investigated the association of postoperative respiratory complications and IPI scores in PACU. However, we examined the relationship between the IPI scores at the first 2 hours in the PACU and POCs (respiratory and non-respiratory) within 28 days after surgery. In addition, their patients were at high risk of postoperative hypoventilation (advanced age, higher BMI), but our patients were ASA physical status I-III and generally uneventful. In our study, we observed POCs in 30 patients (30.9%), but we could not find any relationship between POCs and the IPI scores.

One of the causes of adverse respiratory events is the use of opioids for postoperative pain management. Therefore, continuous respiratory monitoring is recommended for safe patient-controlled analgesia[13]. IPI monitoring could also be used to detect opioid-induced respiratory depression[14]. In our study, all patients received general anesthesia and 84.5% of them were administered IV morphine for postoperative analgesia. Respiratory depression or apnea was not observed in any patient. Patients with an IPI score of 6, who may require intervention (13 patients at 30 minutes, 2 patients at 1 hour, 2 patients at 2 hours), were followed-up without any problems due to close nurse observation in the PACU. None of them required any intervention.

In the literature, few studies have investigated the correlation between the IPI scores and blood gas analysis. In these studies, a significant correlation was observed between the IPI score, and SpO_2 and RR[15]. This is actually an expected result, since SpO_2 and RR are parameters used in the calculation of the IPI score. The authors also observed a correlation between IPI-SpO_2 value and arterial blood gas-oxygen saturation, and between IPI-$EtCO_2$ value and arterial blood gas-$PaCO_2$ measurement. This result suggests that IPI monitoring could be a preferred alternative to arterial blood gas analysis, which is an invasive method, for ICU patients. In another study, physiological status (RR, SpO_2, HR, and $EtCO_2$) was investigated in sedated patients undergoing colonoscopy in low (2-3), medium (4-6) and high (7-10) IPI groups[16]. A difference in $EtCO_2$ values was found between the groups, while the other values were similar. In our study, we also observed a correlation between the IPI score and arterial blood gas analysis (pH, $PaCO_2$ and PaO_2). To our knowledge, this is the first study to investigate the relationship between the IPI scores and hemodynamic variables in postoperative patients. We observed that the IPI scores of patients who were hypertensive and tachycardic within the first 30 minutes in the PACU increased as their hemodynamic values became more stable over time. During this period, none of the patients needed antihypertensive or beta-blocker agents. However, we administered additional analgesic agents to patients experiencing pain.

Our study had some limitations. First, it was conducted during the COVID-19 pandemic, resulting in a lower number of patients than expected. Second, the study population consisted mainly of ASA I and II patients, with only 20.6% being ASA III. In addition, our study did not include patients who were older than 75 years and had a BMI≥40. As a result, this study cannot provide an insight into the use of the IPI in the evaluation of high risk patients (ASA > III, age > 75 years, morbid obesity, etc.). Third, this is a single center study.

In conclusion, IPI monitoring may be a useful tool for early detection in the postoperative care of thoracic surgery patients. However, multicenter, randomized controlled studies with a larger number of patients are needed to investigate the efficacy of IPI monitoring in patients undergoing thoracic surgery.

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