Updates in Surgery
https://doi.org/10.1007/s13304-023-01464-0

ORIGINAL ARTICLE

Erector spine plane block as single loco-regional anesthesia in non-intubated video-assisted thoracic surgery for unfit patients: a case-match study

Roberto Bellini[1] · Maria Chiara Salandini[1] · Stefano Granieri[1] · Andrea Chierici[2] · Rita Passaretta[3] · Christian Cotsoglou[1]

Received: 10 November 2022 / Accepted: 10 February 2023

Abstract
In the present study, we analyzed the safety and efficacy of non-intubated video-assisted thoracoscopy (NI-VATS) for the diagnosis and palliation of malignant pleural effusion in the elderly population using erector-spinae plane block (ESPB) as single loco-regional anesthesia. From January 2016 to December 2020 a consecutive series of 158 patients who underwent surgery for malignant pleural effusion was analyzed. Of these, 20 patients were operated using ESPB NI-VATS, while 138 were operated under general anesthesia (GA). After propensity score matching, the NI-VATS population was older (81 vs. 76 years p 0.006), and had more severe pre-existing comorbidities, evaluated using Charlson Comorbidity Index ($p = 0.029$) and ASA score ($p < 0.001$). GA and NI-VATS patients did not differ in terms of postoperative opioid consumption, complication rate and postoperative hospitalization. Both short- and long-term efficacy of talc poudrage was equal in the two populations. The overall length of stay in the operative room was significantly shorter for the NI-VATS than for the GA-VATS group (67.5 vs. 105 min, $p < 0.001$), and operative time significantly differed in the two groups (35 vs. 47.5 min, respectively, $p < 0.001$). ESPB NI-VATS can be a safe and effective option for the diagnosis and palliation of malignant pleural effusion for elderly and frail patients.

Keywords Erector-spinae plane block · Non-intubated VATS · Loco-regional anesthesia · Elderly patients

Introduction

In the last decades, the general population has faced a growing life expectancy, due to improving socio-economical conditions and to a more profound knowledge and treatment options for many conditions affecting the elderly. Consequently, many patients who might have been considered unfit for surgical procedures and chemotherapy treatment for oncological conditions because of their age and comorbidities can be actually treated with new and targeted therapies [1].

Elderly and frail patients with pleural effusion suspicious for advanced oncological disease can be therefore candidates to targeted and molecular therapy [2], or at least to surgical palliation despite their general conditions, thanks to new minimally invasive techniques such as non-intubated video-assisted thoracic surgery (NI-VATS) [3–5].

One of the key points of multi-modal approach in minimally invasive surgery is perioperative analgesia. In the last years, different thoracic blocks have been introduced in order to provide a safe and long-lasting analgesic effect in patients who underwent VATS surgery. In particular, erector spinae plane block (ESPB) was first described in 2016 [6] and represents a valid and safe alternative in pain management of VATS patients [7, 8]. However, except for anecdotal reports [9–11], its systematic use as the only loco-regional anesthesia in NI-VATS has not yet been investigated.

Roberto Bellini and Maria Chiara Salandini equally contributed to the present work and as co-first authors.

✉ Maria Chiara Salandini
mariachiara.salandini@asst-brianza.it

1 General Surgery Unit, ASST-Brianza, Vimercate Hospital, Via Santi Cosma e Damiano, 10, 20871 Vimercate, Italy

2 Service de Chirurgie Digestive, Centre Hospitalier d'Antibes Juan-Les-Pins, 107, av. de Nice, 06600 Antibes, France

3 Anesthesia and Resuscitation Unit, ASST-Brianza, Vimercate Hospital, Via Santi Cosma e Damiano, 10, 20871 Vimercate, Italy

Published online: 23 February 2023

In this paper, we compared retrospectively collected data and outcomes of 20 elderly "unfit" patients treated with diagnostic and palliative NI-VATS for malignant pleural effusion to 138 patients who underwent the same procedure under general anesthesia.

Materials and methods

Since the introduction of our thoracic surgery unit in ASST-Brianza, Vimercate Hospital in 2016, until December 2020, all patients who consecutively underwent VATS for pleural biopsies and talc pleurodesis for suspected malignant pleural effusion were included in the study. Demographic data, details of patients' comorbidities including Charlson Comorbidity Index, American Society of Anesthesiologist (ASA) score, characteristics of surgery, operative times, details of postoperative course, postoperative morbidity and mortality rates, and length of hospitalization were collected and retrospectively analyzed. Surgical failure was defined as effusion relapse as documented on preoperative X-ray by an experienced radiologist, or as recurrence of dyspnea at discharge, at 15-, or 30-day follow-up.

Routinely, general anesthesia was offered to all patients, unless they were declared unfit by the anesthesiologist based on age, ASA score, pre-existent respiratory failure with need of continuous nasal-flow oxygen, pre-existent comorbidities or unless refusal of intubation by the patient. Patients with neurological impairment (such as dementia), that might compromise proper autonomic ventilation and collaboration of the patient throughout the procedure, where excluded from ESPB NI-VATS. Difficulty in maintaining lateral decubitus because of orthopedic conditions or persistent coughing was not an exclusion criterion, as in that case the patient was kept in a 30 to 45 degrees supine position.

Ultrasound-guided erector spinae plane block

After arrival in the preoperative room, patients were placed in a sitting position on the operating bed. The T4 spinous process was identified by palpation of the spinous processes from C7 downward. Using an ultrasound linear array transducer, the erector spinae muscle plane was identified by placing the probe in a paramedian sagittal plane at the T4 level. With aseptic technique, a 90-mm 22-gauge needle was inserted in-plane to the ultrasound beam in the cranio-to-caudal direction to contact the interfascial plane between the erector spinae muscle and the transverse process.

Once the correct location of the tip of the needle was confirmed, 20 mL of ropivacaine cloridrate 0.75% was injected, with subsequent extensive spread of local anesthetic lifting the erector spinae muscle. All ESPB were performed by the same experienced anesthesiologist (P.R.). All procedures did not exceed 10 min. ESPB block was performed 20–40 min before entering operative room.

Once the patient was placed in the correct position and the intervention got started, à-la-demande mild sedation was obtained using midazolam or propofol with a target bispectral index (BIS) score between 70 and 80 [12], if the patient was feeling anxiety or discomfort due to surgical manipulation or prolonged lateral decubitus. No local anesthesia was used in the site of surgical incision.

If patients presented with persistent cough, aerosol with of saline solution with 5 mL of 2% lidocaine was given after ESPB was performed.

Low-flow oxygen with Venturi mask was given through the whole intervention.

During surgical intervention the patients were monitored using ECG registration, non-invasive arterial pressure, pulse oximetry and BIS.

General anesthesia

After anesthesia induction and neuromuscular blockade with rocuronium, patients were intubated using a double-lumen tube under flexible bronchoscopy guidance. Anesthesia was maintained with sevoflurane and remifentanil infusion. Intraoperative monitoring was obtained with ECG registration, peripheral pulse oximetry, end-tidal carbon dioxide detection and non-invasive arterial blood pressure.

Before extubation, an intravenous bolus of 3–5 mg morphine was administered to the patient. Postoperative nasal-flow oxygen was given both to NI and general anesthesia (GA)-VATS patients for at least 24 h after surgery (2 or 4 L/min). If the patient underwent GA, ESPB block was not performed, and standard postoperative opioid-based analgesia was administered.

Surgical setup

Patients with suspected malignant pleural effusion were enrolled. If the patient was symptomatic for dyspnea, or massive pleural effusion was detected, 24 h prior to surgery a chest drain tube was inserted in the 5th or 6th intercostal space in order to drain the effusion and get lung expansion.

Once in the operating room, the patient was placed in lateral decubitus, using a vacuum mattress that helped the patient to maintain the proper position throughout the whole intervention effortlessly. Occasionally, the procedure was performed with the patient in a 30–45° supine position if the patient could not maintain lateral decubitus because of coughing or orthopedic conditions. In one case, 60° sitting position was adopted due important cough if the patient tried to lay furtherly down.

After general anesthesia was induced and the indicated lung excluded, or after ESPB was performed and the patient

positioned, a 3 cm incision in the 5th or 6th intercostal space along the midaxillary line was performed. Usually, a second port in the 8th intercostal space along the posterior axillary line was inserted. Pleural-parenchymal adhesiolysis was performed unless tight adhesions were retrieved, and residual effusion removed. Posterior and lateral parietal partial pleurectomy of at least 4 cm^2, or multi-site parietal pleura biopsies were performed, and pleurodesis was obtained by instillation of 8 g of talc powder. At the end of the intervention, two 28 Chevrel chest tubes were left the anterior-apical drain was inserted through the first incision, while the posterior-basal through the latter one. In both ESPB NI-VATS and GA-VATS the identical surgical technique and setup were used.

A continuous 20 cmH_2O suction was applied to both drains for 4 days to facilitate pleurodesis, and they were removed on the 4th postoperative day (POD). The patient was then discharged on POD5 unless clinical needs arose meanwhile.

Postoperative pain control was obtained by administration of intravenous ketorolac 30 mg three times a day, plus on-demand subcutaneous 5 mg morphine for no more than 4 times daily if pain control was not achieved.

Both general and loco-regional patients received the same postoperative analgesia regimen.

Statistical analysis

Based on the different types of anesthesia, the sample was split into general anesthesia (GA)-VATS and ESPB NI-VATS groups. Data were recorded in a computerized spreadsheet (Microsoft Excel 2016; Microsoft Corporation, Redmond; WA) and analyzed with statistical software (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY). Propensity Score Matching (PSM) was performed to adjust for differences in the baseline characteristics in the two groups. A one-to-one, nearest neighbor, logistic regression matching model was built setting the maximum tolerated difference between matched subjects (caliper) at 0.2 standard deviations (SD). Univariate analysis was carried out to identify variables responsible for pre-match imbalance. Age, ASA score and Charlson Comorbidity Index were selected as potential confounders and entered in the model. Graphical (histogram of propensity score, dot-plot of standardized differences) and mathematical (standardized differences, L1 test) balance diagnostics were evaluated before and after matching for an accurate assessment of the goodness of our model.

The distribution of the sample per each variable of interest was assessed with Shapiro–Wilk test. Differences in proportions were evaluated with Pearson's χ^2 or Fisher's test, whereas independent samples Mann–Whitney test was used to compare continuous variables.

Primary and secondary endpoints

The primary endpoint of the study was to assess the safety of ESPB NI-VATS compared to GA-VATS. It was defined as the incidence of any postoperative complication according to the Clavien–Dindo classification.

As secondary endpoints, we analyzed the efficacy of ESPB NI-VATS and compared it to GA-VATS. As secondary outcome variables we selected the relapse of pleural effusion at discharge, 15-, and 30-days, and the need for postoperative opioid analgesia. This latter variable was defined as the number of on-demand morphine administrations each postoperative day.

Furthermore, as exploratory outcomes we wanted to assess possible differences in operative times and length of hospitalization between the two groups. A two-tailed p value < 0.05 was considered statistically significant.

Due to the retrospective nature of the study, an ethical review board approval was not deemed necessary.

Results

Data of 279 patients consecutively treated at our Center during the study period were collected. According to the exclusion criteria mentioned above, 158 patients were selected from the registry, 138 of whom were in the standard GA-VATS group and 20 in the ESPB NI-VATS group.

Median age was higher in the ESPB NI-VATS than in GA-VATS group (81 years, IQR: 73–89 vs. 76 years IQR: 70–81; p 0.006). The incidence of specific pre-existing comorbidities (i.e. atrial fibrillation, congestive heart failure, respiratory insufficiency, chronic kidney disease, type II diabetes, autoimmune diseases), Charlson Comorbidity Index ($p = 0.029$) and ASA score ($p < 0.001$) were significantly higher in patients undergoing awake surgery than general anesthesia. However, postoperative morbidity rates were equivalent in the two groups ($p = 0.53$). No complications related to ESPB were registered in the NI-VATS patients.

Further characteristics of the sample are reported in Table 1.

Eighteen couples of patients were eligible after propensity score matching. Graphical assessment of balance before and after matching is displayed in Fig. 1.

For a more objective evaluation of balance diagnostic, we computed pre- and post-matching standardized differences of the selected confounders. For all covariates, we observed a small effect size, defined by a standardized difference value below 0.2 after matching (Table 2).

When analyzing the primary endpoints of the study, additional overall opioid consumption did not vary in the GA-VATS and the ESPB NI-VATS patients. Moreover, opioids

Table 1 Demographic and epidemiological data in GA-VATS, ESPB NI-VATS groups, and overall population

Variables	GA-VATS (138)		ESPB NI-VATS (20)		Total (158)		*p*
	Value	%	Value	%	Value	%	
Age (median—IQR)	76	70–81	81	73–89	77	70–82	*0.006*
Gender							0.81
Male	85	61.6	13	65	98	62	
Female	53	38.4	7	35	60	38	
Comorbidities							
Atrial fibrillation	19	13.8	7	35	26	16.5	*0.025*
Congestive heart failure	21	15.2	10	50	31	19.6	*0.001*
Respiratory failure	6	4.3	6	30	12	7.6	*0.001*
Chronic kidney disease	13	9.4	6	30	19	12	*0.018*
Type II diabetes	16	11.6	3	15	19	12	0.71
Autoimmune diseases	7	5.1	1	5	8	5.1	1
Disease leading to pleural effusion							0.57
Chronic inflammation	41	29.7	8	40	49	31	
Mesothelioma	41	29.7	2	10	43	27.2	
Metastases from lung carcinoma	29	21	6	30	35	22.2	
Metastases from pancreatic carcinoma	2	1.4	1	5	3	1.9	
Metastases from breast cancer	8	5.8	1	5	9	5.7	
Metastases from gastric cancer	3	2.2	0	0	3	1.9	
Metastases from urothelial carcinoma	3	2.2	1	5	4	2.5	
Metastases from ovarian carcinoma	4	2.9	0	0	4	2.5	
Lymphoma	3	2.2	1	5	4	2.5	
Sarcoma	4	2.9	0	0	4	2.5	
ASA score							*< 0.001*
II	45	32.6	1	5	46	29.1	
III	92	66.7	15	75	100	67.7	
IV	1	0.7	4	20	5	3.2	
Charlson comorbidity index (Median—IQR)	7	5–9	8	6–10	7	5–9	*0.029*

Significant values are reported in italics

consumption at any specific time point (i.e., postoperative day 0, 1, 2 and 4), was equivalent in the two groups.

Furthermore, the incidence of pleural effusion relapse at discharge (5.6% vs. 11.1%, $p = 1$), at 15 (5.6% vs. 22.2%, $p = 0.338$) and 30 (16.6% vs. 22.7%, $p = 1$) days did not increase in the ESPB NI-VATS patients compared to GA-VATS. Likewise, the postoperative complication rate according to Clavien–Dindo [13] classification was similar in both groups ($p = 0.53$) (Table 3).

Patients who underwent locoregional anesthesia had shorter preoperative time (22.5 min, IQR: 10–40 vs. 45 min, IQR: 25–50; $p = 0.004$), intraoperative time (35 min, IQR: 30–40 vs. 47.5 min, IQR: 40–55; $p = 0.005$), postoperative/awakening time (10 min, IQR: 10.0–10.0 vs. 20 min, IQR: 15–25; $p < 0.001$) and overall stay in the operative room (67.5 min, IQR: 60–85 vs. 105 min, IQR: 90–125; $p < 0.001$). No difference in length of stay between the two groups was found (I-VATS 5 days, IQR: 5–5; ESPB NI-VATS 6 days, IQR: 5–6; p 0.252).

Discussion

Elderly and frail patients with advanced cancer have often been considered unfit for oncological treatments because of their age and comorbidities; in particular, palliation of malignant pleural effusion is usually not taken into consideration because of high surgical risks in a population with little or no treatment options. However, the introduction of new and targeted therapies for different cancers, such as immunotherapy in lung cancer [2], can make this specific population eligible for selected drug regimens. Moreover, quality of life is nowadays a very important goal in oncological patients, and clearance of respiratory insufficiency due to abnormal pleural effusion in advanced cancer ought to be pursued, whenever possible [14, 15].

While most of thoracic interventions are preferably conducted under general anesthesia, still mechanical ventilation can cause different problems such as lung injuries, which may in turn be worsened by prolonged surgical procedure

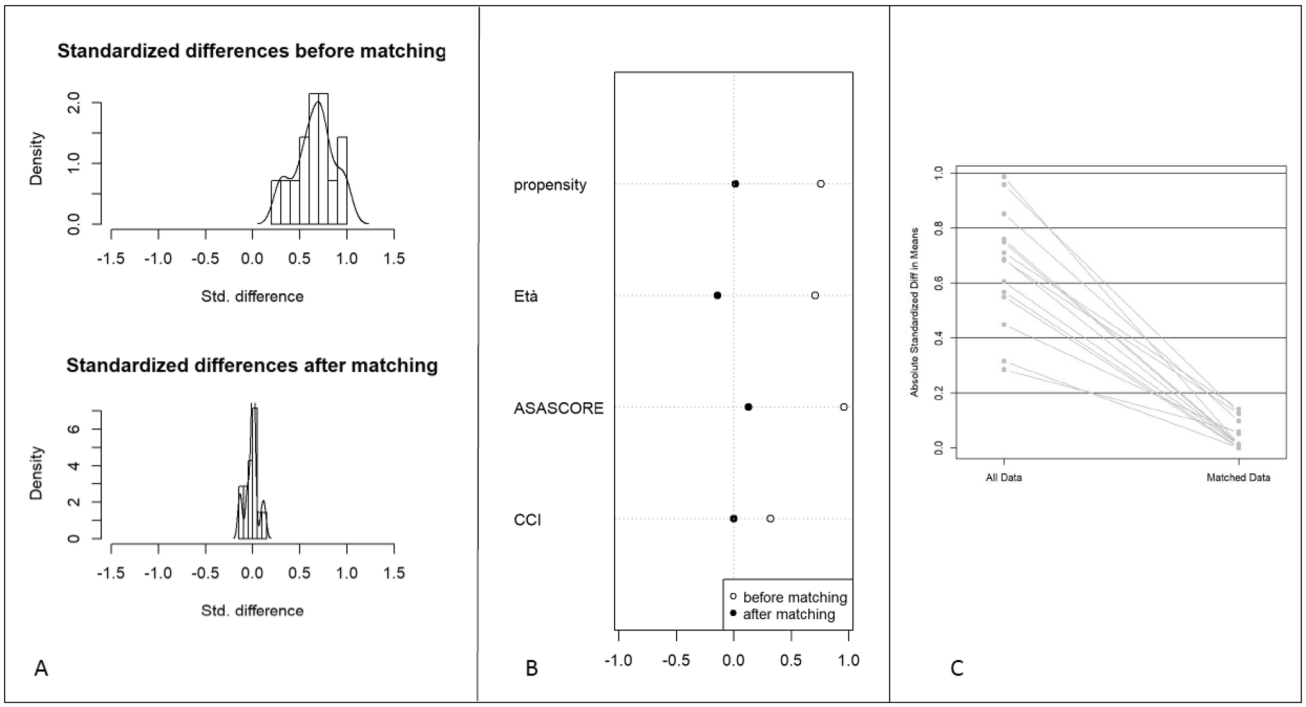

Fig. 1 Graphical assessment of balance between GA-VATS and NI-VATS patients. **A** Density plot of propensity score; **B** dot plot of propensity score; **C** standardized differences

Table 2 Propensity score covariates and coefficients after matching

	Means treated		Means control		SD control		Std. mean diff.	
	Before	After	Before	After	Before	After	Before	After
Propensity	0.291	0.196	0.103	0.193	0.089	0.141	0.759	0.015
Age	80.65	78.375	73.804	79.75	10.501	7.497	0.71	− 0.143
ASA score	3.15	3	2.681	2.938	0.483	0.443	0.958	0.128
Charlson Comorbidity Index	7.8	7.313	6.964	7.313	2.64	2.983	0.316	0

and extent of lung resection. Moreover, single lung ventilation naturally generates pulmonary atelectasis with intrapulmonary artero-venous shunt in the excluded lung, which may not fully recover at the end of the intervention if the lung is not carefully re-expanded using positive end-expiratory pressure (PEEP) [6]. Pulmonary atelectasis might, in turn, worsen during the first postoperative days especially in the elderly, who are less prone to early mobilization and coughing than young and fit patients. Keeping both lungs ventilated with loco-regional anesthesia might help to avoid lung injuries intraoperatively as well as pulmonary atelectasis in the postoperative period, thus favoring a quicker recovery of the patient [4, 5, 16].

Local anesthesia may cause some discomfort both to the patient and the surgeon during intervention. In particular, its efficacy is limited to the surgical incision area, and therefore parietal pleural sensitivity during adhesiolysis and pleural biopsies can cause significant pain to the patient and may represent a technical challenge for the surgeon. On the other hand, epidural anesthesia as locoregional anesthesia may lead to some complications, such as epidural hematoma, dural puncture, hypotension, or urinary retention [17].

In the last years, different thoracic blocks such as paravertebral, erector spinae plane, serratus plane and intercostal plane blocks have been described and they represent a novel and rapidly expanding field of regional anesthesia [18].

Among these, ESPB plays an important role in pain management after breast, cardiac and abdominal surgery [19–21], where it can be used as single shot, intermittent or continuous infusion.

It also seems to improve control of chronic thoracic pain in different situations such as multiple rib fractures, therefore improving respiratory outcomes [22].

Table 3 Primary and secondary endpoints evaluation: pleural effusion relapse, complication incidence, operative time, and length of stay

Variables	GA-VATS (18)		ESPB NI-VATS (18)		*p*
	Value	%	Value	%	
Pleural effusion relapse					
Discharge	1	5.6	2	11.1	1
15 days	1	5.6	4	22.2	0.34
30 days	3	16.6	4	22.2	1
Clavien–Dindo complications					0.53
0	15	83.3	15	83.3	
1	0	0	1	5.6	
2	1	5.6	2	11.1	
3	1	5.6	0	0	
4	0	0	0	0	
5	1	5.6	0	0	
Total	3	16.7	3	16.7	
Operative times (Median—IQR)					
Preoperative time	45	25–50	22.5	10–40	*0.004*
Intraoperative time	47.5	40–55	35	30–40	*0.005*
Postoperative time	20	15–25	10	10–10	*< 0.001*
Total time	105	90–125	67.5	60–85	*< 0.001*
Length of stay (Median—IQR)	5	5–5	6	5–6	0.25

Significant values are reported in italics

Although ESPB provides excellent postoperative analgesia, so far its use as the only anesthesia in non-intubated surgery is only anecdotal [9, 11].

Based on these considerations, we have decided to adopt ESPB as standard loco-regional anesthesia approach for patients who were considered unfit for GA. Our first goal was to assess the feasibility and safety of this approach: in our series, all patients eligible for ESPB NI-VATS were able to get through surgical intervention with no need to switch to GA, and no complications related to ESPB was registered. The first advantage of ESPB compared to local anesthesia and to epidural anesthesia is that it carries less procedures-related complications, as well as providing excellent pain control of visceral pleura during biopsies or partial pleurectomy. This might be explained by anatomical investigations that show how ESPB works through two mechanisms: the paravertebral block (PVB) pathway and the lateral pathway [23]. First, the PVB pathway involves both ventral and dorsal spinal rami. Second, the lateral pathway involves the lateral cutaneous branch and small branches of intercostal nerves. The blockade of these cutaneous branches of intercostal nerves can provide a certain level of analgesia for the hemithorax.

The second aspect is intraoperative timing: a prolonged awake surgery in an elderly and frail patient might represent a tremendous effort in terms of physical and psychological stress. Keeping the same position for several minutes, trying not to cough while having an induced pneumothorax, and tolerating a general discomfort with possibly some degree of pain might be overwhelming.

In our study, both preoperative, intraoperative, and postoperative times were significantly reduced in the NI-VATS group compared with the GA-VATS patients: in particular, surgical timing was reduced by one third (35 vs. 48 min).

In awake surgery, the use of the vacuum mattress is crucial in helping the patient to maintain the same position for a prolonged time, without relying only on his own effort and consistency. This tool provides great comfort for the patient throughout the whole intervention, as well as guaranteeing a greater stability of the operative field, thus avoiding sudden and dangerous changes in the patient position.

Postoperative pain control in thoracic surgery patients is crucial to obtain a good coughing strength to avoid pulmonary atelectasis, and to get a rapid recovery. Typically, the longer a frail and old patient stays in bed, the higher the risk of pneumonia, respiratory failure and decubitus wounds. In a recent randomized-controlled trial by Fiorelli and colleagues, 60 patients who were candidates to mini-thoracotomy for general anesthesia thoracic surgery were given either preoperative ESPB or intraoperative intercostal nerve block: in the former group pain control was significantly better and opioids consumption significantly lower than in the latter, thus leading to a less respiratory muscle length impairment (measured by maximum inspiratory and expiratory pressure) in the ESPB group [24]. These results were confirmed by Chaudhary et al., who found that compared to intercostal nerve block in patients who underwent VATS or robotic-assisted thoracic surgery under GA, ESPB improved acute and chronic pain control and preserved lung function, measured with bedside spirometry right after surgery and 24 h postoperatively [25].

Although in the present study opioid consumption did not vary between GA-VATS and NI-VATS patients, thus suggesting that pain control and patient satisfaction did not improve in the latter group, still ESPB provides excellent pain control during surgical intervention, with no pitfalls in the postoperative period.

Finally, postoperative complications, length of stay and rate of effusion relapse did not vary between the two groups: these results demonstrated not only that ESPB NI-VATS surgery can be safely performed in frail patients, but also that it can be accomplished with a high quality and long-lasting level of efficacy.

In 2014, Mineo et al. compared non-intubated surgery versus intubated VATS for malignant pleural effusion [26]: in his paper 231 patients who underwent non intubated

surgery with intercostal nerve block experienced the same efficacy as intubated patients, with better surgical outcome and improved quality of life. However, in this studio the choice of whether to undergo local or general anesthesia was made by the patient himself. To our knowledge, this is the first studio where loco-regional anesthesia was given specifically to frail patients who were not eligible to general anesthesia because of their comorbidities.

Our results are therefore even more meaningful if we take into consideration that, although post-matching analysis has been conducted on similar groups, baseline comparison demonstrated that mean age, ASA score and CCI were significantly higher in ESPB NI-VATS patients: diagnostic and/or palliative thoracoscopy can therefore be safely and effectively offered to elderly and frail patients using loco-regional anesthesia, with very little anesthesiologic risk.

This study has some limitations: first, its retrospective nature, and secondly its relatively small sample size. Moreover, specific variables, such as postoperative patient mobilization, respiratory performance and patient satisfaction has not been specifically studied. This could represent the starting point for further, more comprehensive research about the potential advantages of this innovative technique.

Author contributions Conceptualization, RB and MCS; methodology, SG and AC; software, SG.; validation, RB, MCS, SG, and AC, and CC; formal analysis, XX; investigation, RB, MCS, SG, and AC; data curation, SG; writing—original draft preparation, MCS, RB, and SG; writing—review and editing, MCS, RB, SG, and AC; visualization, RB, MCS, SG, AC, RP, and CC; supervision, RB and CC; project administration, RB and MCS. All authors have read and agreed to the published version of the manuscript.

Funding This research received no external funding.

Data availability The datasets used during the present study are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Institutional review board statement Due to the retrospective nature of the study, an institutional review Board approval was not required.

Informed consent Written informed consent has been obtained from the patients to publish this paper.

References

1. Bassi MA, Lopez MA, Confalone L, Gaudio RM, Lombardo L, Lauritano D (2020) Enhanced reader.Pdf. Nature 388:539–547
2. Ruiz-Cordero R, Devine WP. Targeted therapy and checkpoint immunotherapy in lung cancer. Surg Pathol Clin. 2020;13(1):17–33. https://doi.org/10.1016/j.path.2019.11.002.
3. Katlic MR (2021) Five hundred seventy-six cases of video-assisted thoracic surgery using local anesthesia and sedation: lessons learned. J Am Coll Surg 226:58–63. https://doi.org/10.1016/j.jamcollsurg.2017.09.017
4. Katlic MR, Facktor MA (2015) Non-intubated video-assisted thoracic surgery in patients aged 80 years and older. Ann Transl Med 3:1–6. https://doi.org/10.3978/j.issn.2305-5839.2015.04.01
5. Wu CY, Chen JS, Lin YS, Tsai TM, Hung MH, Chan KC, Cheng YJ (2013) Feasibility and safety of nonintubated thoracoscopic lobectomy for geriatric lung cancer patients. Ann Thorac Surg 95:405–411. https://doi.org/10.1016/j.athoracsur.2012.10.082
6. Forero M, Adhikary SD, Lopez H, Tsui C, Chin KJ (2016) The erector spinae plane block a novel analgesic technique in thoracic neuropathic pain. Reg Anesth Pain Med 41:621–627. https://doi.org/10.1097/AAP.0000000000000451
7. Yao Y, Fu S, Dai S, Yun J, Zeng M, Li H, Zheng X. Impact of ultrasound-guided erector spinae plane block on postoperative quality of recovery in video-assisted thoracic surgery: A prospective, randomized, controlled trial. J Clin Anesth. 2020;63:109783. https://doi.org/10.1016/j.jclinane.2020.109783.
8. Pirsaharkhiz N, Comolli K, Fujiwara W, Stasiewicz S, Boyer JM, Begin EV, Rubinstein AJ, Henderson HR, Lazar JF, Watson TJ, Eger CM, Trankiem CT, Phillips DG, Khaitan PG. Utility of erector spinae plane block in thoracic surgery. J Cardiothorac Surg. 2020;15(1):91. https://doi.org/10.1186/s13019-020-01118-x.
9. Hu B, Zhou H, Zou X (2021) The erector spinae plane block (ESPB) for non-intubated video-assisted thoracoscopic surgery. J Clin Anesth 54:50–51. https://doi.org/10.1016/j.jclinane.2018.10.032
10. Ueshima H, Otake H (2017) Erector spinae plane block provides effective pain management during pneumothorax surgery. J Clin Anesth 40:74
11. Longo F, Piliego C, Tomaselli E, Martuscelli M, Agrò FE (2020) Erector spinae plane block allows non-intubated vats-wedge resection. J Clin Anesth 60:89–90
12. Radtke FM, Franck M, Lendner J, Krüger S, Wernecke KD, Spies CD (2013) Monitoring depth of anaesthesia in a randomized trial decreases the rate of postoperative delirium but not postoperative cognitive dysfunction. Br J Anaesth 110:98–105. https://doi.org/10.1093/bja/aet055
13. Dindo D, Demartines N, Clavien PA (2004) Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 240:205–213. https://doi.org/10.1097/01.sla.0000133083.54934.ae
14. Terra RM, Costa PB, Dela Vega AJM, Araujo PHXN, Teixeira LR, Pêgo-Fernandes PM (2019) Analysis of quality of life after pleurodesis in patients with malignant pleural effusion. Respiration 98:467–472. https://doi.org/10.1159/000502029
15. Dipper A, Jones HE, Bhatnagar R, Preston NJ, Maskell N, Clive AO (2020) Interventions for the management of malignant pleural effusions: a network meta-analysis. Cochrane Database Syst Rev. https://doi.org/10.1002/14651858.CD010529.pub3
16. Deng HY, Zhu ZJ, Wang YC, Wang WP, Ni PZ, Chen LQ (2016) Non-intubated video-assisted thoracoscopic surgery under loco-regional anaesthesia for thoracic surgery: a meta-analysis. Interact Cardiovasc Thorac Surg 23:31–40. https://doi.org/10.1093/icvts/ivw055
17. Yeung JH, Gates S, Naidu BV, Wilson MJ, Gao Smith F (2016) Paravertebral block versus thoracic epidural for patients undergoing thoracotomy. Cochrane Database Syst Rev. https://doi.org/10.1002/14651858.CD009121.pub2
18. Helander EM, Webb MP, Kendrick J, Montet T, Kaye AJ, Cornett EM, Kaye AD. PECS, serratus plane, erector spinae, and paravertebral blocks: A comprehensive review. Best Pract Res Clin Anaesthesiol. 2019;33(4):573–81. https://doi.org/10.1016/j.bpa.2019.07.003.

19. ElHawary H, Abdelhamid K, Meng F, Janis JE. Erector spinae plane block decreases pain and opioid consumption in breast surgery: systematic review. Plast Reconstr Surg Glob Open. 2019;7(11):e2525. https://doi.org/10.1097/GOX.0000000000002525.
20. Macaire P, Ho N, Nguyen T (2021) Ultrasound-guided continuous thoracic erector spinae plane block within an enhanced recovery program is associated with decreased opioid consumption and improved patient postoperative rehabilitation after open cardiac surgery—a patient-matched. Control J Cardiothorac Vasc Anesth 33:1659–1667. https://doi.org/10.1053/j.jvca.2018.11.021
21. Macaire P, Ho N, Nguyen T, Nguyen B, Vu V, Quach C, Roques V, Capdevila X. Ultrasound-Guided Continuous Thoracic Erector Spinae Plane Block Within an Enhanced Recovery Program Is Associated with Decreased Opioid Consumption and Improved Patient Postoperative Rehabilitation After Open Cardiac Surgery-A Patient-Matched, Controlled Before-and-After Study. J Cardiothorac Vasc Anesth. 2019;33(6):1659–67. https://doi.org/10.1053/j.jvca.2018.11.021.
22. Adhikary SD, Liu WM, Fuller E, Chin KJ (2019) The effect of erector spinae plane block on respiratory and analgesic outcomes in multiple rib fractures: a retrospective cohort study*. Anaesthesia. https://doi.org/10.1111/anae.14579
23. Onishi E, Toda N, Kameyama Y, Yamauchi M, Ueshima H (2019) Comparison of clinical efficacy and anatomical investigation between retrolaminar block and erector spinae plane block. Biomed Res Int. https://doi.org/10.1155/2019/2578396
24. Fiorelli S, Leopizzi G, Menna C, Teodonio L, Ibrahim M, Rendina EA, Ricci A, De Blasi RA, Rocco M, Massullo D (2020) Ultrasound-guided erector spinae plane block versus intercostal nerve block for post-minithoracotomy acute pain management: a randomized controlled trial. J Cardiothorac Vasc Anesth 34:2421–2429. https://doi.org/10.1053/j.jvca.2020.01.026
25. Chaudhary O, Baribeau Y, Urits I, Sharkey A, Rashid R, Hess P, Krumm S, Fatima H, Zhang Q, Gangadharan S et al (2020) Use of erector spinae plane block in thoracic surgery leads to rapid recovery from anesthesia. Ann Thorac Surg 110:1153–1159. https://doi.org/10.1016/j.athoracsur.2020.03.117
26. Mineo TC, Sellitri F, Tacconi F, Ambrogi V (2014) Quality of life and outcomes after nonintubated versus intubated video-thoracoscopic pleurodesis for malignant pleural effusion: comparison by a case-matched study. J Palliat Med. https://doi.org/10.1089/jpm.2013.0617