Early air transport after thoracic surgery might be safe: A retrospective observational study in the French Caribbean

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ABSTRACT

Objective: The objective of this study was to determine the incidence of early air transport (EAT) morbidity after transpleural surgery. We compared our cohort with our patients not requiring air transport.

Methods: This was a retrospective observational study, in the Thoracic and Cardiovascular Surgery Department of the University Hospital of Martinique over 40 months. We included all of the files (national and local database, and systematic postoperative consultation) of patients operated on for thoracic surgery or distinguished transpleural surgical intervention, whatever their geographical origin. Patients from another French department benefited from EAT. The complications were classified according to Clavien–Dindo before or after the EAT. Diagnostic criteria were chest pain, dyspnea, and abnormal chest radiograph. Continuous variables are presented as mean, median, and SDs. Discrete variables are presented as n (%).

Results: Of 491 patients operated on, 315 were transpleural surgeries, and 99 patients benefited from EAT. There were 55% resections, a percent predicted of forced expiratory volume in 1 second, and an average preoperative Tiffeneau ratio of respectively, 86% and 78. One complication was found: a pneumothorax in an emphysematous patient, 15 days after the flight, who had an index of prolonged air leak >10. The mean time between surgery and flight was 7.2 days ($\sigma = 4.5$), and 3.3 days ($\sigma = 2.9$) between removal of the last drain and flight. The morbidity of EAT after transpleural surgery was 1%. The 2 cohorts of "EAT" and "Locals" patients were statistically comparable, particularly in morbidity.

Conclusions: EAT appears to be safe after transpleural surgery, following usual criteria for hospital discharge. It would be interesting to study, on a larger scale, the effect of IPAL as an independent risk factor (in case of high IPAL > 10) as well as pathologies that modify transpleural pressures restrictive ventilatory defect. (JTCVS Open 2022;9:333-9)

Early air transport after thoracic surgery.

CENTRAL MESSAGE

The issue of air transport after thoracic surgery is recurrent: this retrospective observational study showed 1% morbidity after early air transport with usual criteria for hospital discharge.

PERSPECTIVE

Recommendations regarding the safety and timing of air travel after thoracic surgery have, to date, been solely on the basis of theoretical concerns and expert opinion. The current study provides arguments and objective clinical data that shows the safety of air travel after transpleural surgery; the average time between the removal of the last chest drain and the flight in our study was 3.3 days.

The time frame for allowing air transport (AT) after thoracic surgery is still under discussion. It is an old thoracic surgery dogma to take the necessary perspective before letting patients fly. The theoretical in-flight risk of medical complications, especially the risk of pneumothorax, is involved. This issue is on the basis of the postulate that the increased altitude, and concomitant decrease in atmospheric pressure, would modify transpleural pressures.

The current recommendations are from aviation agencies and are not on the basis of any valid scientific studies. These time frames range from 8 days to 6 weeks.[1-5] In 2010, a survey of thoracic surgeons in the United States showed an average recommended delay of 12 days, and that 46% of them allowed patients to fly with a residual pneumothorax visible after removal of the last chest tube.[6]

Our recruitment pool extends from Saint Barthelemy in the north to French Guyana in the south. The insularity of the West Indies makes AT crucial for patients from outside of Martinique. It was essential to know whether failure to respect the time limit before AT led to postoperative complications. We therefore searched for the incidence of

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Abbreviations and Acronyms

AT = air transport
EAT = early air transport
IPAL = index of prolonged air leak
RVD = restrictive ventilatory defect

complications, mainly pneumothorax, related to early AT (EAT) after transpleural surgery.

METHODS

This study was a descriptive and retrospective observational study of all patients who underwent thoracic surgery at the University Hospital of Martinique between October 1, 2016, and February 7, 2020. The EAT was defined as a flight performed as soon as the patient was discharged from the hospital, without delay.

The main objective of the study was to know the complication rate after EAT. The secondary objective was to compare the complication rate of patients who had benefited from an EAT with that of patients operated on during the same period and who had not had an EAT ("Locals" cohort).

All of the files of patients (regardless of geographical origin) who were operated on for thoracic surgery in the Thoracic and Cardiovascular Surgery Department of the Martinica University Hospital (MUH) from October 1, 2016, to February 7, 2020, were collected. Among them, transpleural surgical procedures were distinguished from other procedures. The patients who had undergone transpleural surgery, and were proposed for a postoperative EAT (patients originating from a department other than that of Martinique—other French Caribbean island) were selected for our main cohort. The other patients, of Martinican origin, represented the "Local" group and did not travel via airplane within 30 days of the operation (Figure 1).

The flights were carried out on board of A330-200 and A330-300 aircraft for French Guyana, and ATR72 and A320 aircraft for Guadeloupe, Saint Barthelemy, and Saint Martin. Flight times varied from 40 minutes to 3 hours and included a maximum of 1 stopover. The real altitude of these aircraft was between 5000 and 12000 m in flight, for a maximum cabin altitude of 2400 m, imposed by the International Civil Aviation Organization.

The patients included were of legal age, affiliated with social security, had undergone transpleural surgery, and their geographical origin had to impose an EAT. Pregnant women (all stages) were not included. Exclusions included: EAT refusals, local recoveries, patients discharged against medical advice, those deceased before EAT, and those discharged with chest drainage or oxygen therapy. Patients with a nonthoracic medical contraindication to EAT were excluded. Patients who were lost to follow-up after EAT were considered to have died of a postoperative complication related to EAT.

After surgery, a radiographic control was performed in the recovery room. The chest drainage was maintained in a soft suction pressure of -20 cm H_2O. It was removed if there was no bubbling for more than 6 hours and if it brought back <200 mL in 24 hours. Discharge from hospital met the usual criteria: normal chest radiograph after removal of the last drain, and normal vital signs (blood pressure, heart rate, temperature, O_2 saturation >92%). In case of pneumonectomy, flight was authorized in the absence of ballooning of the cavity.

A precribed chest radiograph was performed at landing, in a radiology office of their choice. All patients were given postoperative antithrombotic prophylaxis and were seen in a postoperative consultation with a control radiograph at 3 weeks after discharge. The data collected in our local and national Registry of patients operated on by a thoracic surgeon (EPITHORdatabase) (approved by the French Data Protection Authority), were: demographic (age, sex), pneumological history and preoperative spirometry data (forced expiratory volume in 1 second, Tiffeneau ratio, and forced vital capacity), cardiac history and cardiovascular risk factors (smoking status, hypertension, diabetes, obesity), the type of pathology justifying surgery (tumor, infectious, inflammatory, traumatic, or degenerative pathology), the type of intervention (parenchymal resection or other), the type of resection (anatomical or not), the approach (videothoracoscopy, exclusive open surgery, or video-assisted surgery), and the different delays between the intervention, removal of the chest drain, and the EAT (Table 1).

Postoperative complications occurring within 30 days were classified according to the Clavien–Dindo classification, and according to period of occurrence: before, and during or after EAT (considered as EAT-related). Pneumothorax was suspected if chest pain and/or dyspnea was present, confirmed by a chest radiograph, as recommended by the French Health Authorities.[7] Data analysis was performed using EXCEL software version 15.33 (Microsoft Corporation). Continuous variables are represented as means, medians, and standard deviations. Discrete variables are represented as n (%). The comparability of the "EAT" and "Locals" groups was carried out using https://biostatgv.sentiweb.fr. The Student and Fisher exact tests (for continuous variables) and the χ^2 test (for discrete variables) were used.

This study was approved by the International Review Board of the University Hospital of Martinique (approval: CHU Martinique reference: 2020/050, 05.14.2020). Patients were informed orally about the risks associated with EAT during the preoperative consultation and then repeated during hospitalization. The information on the use of the data was provided by postal mail. The study was carried out within the framework of the Jardet MR003 law.

RESULTS

Over 40 months, 491 patients underwent thoracic surgery, of whom 315 patients underwent transpleural surgery. One-third were not from Martinique, therefore requiring an AT. Nine were excluded: 2 for local recovery, 5 had chest drains, and 2 died during hospitalization. None were lost to follow-up (Figure 1).

Our EAT cohort consisted of 99 patients, aged 56.12 years ($\sigma = 16.54$), with 56% male. Thirty-eight percent of the patients had a pneumological history, of whom 18.4% had restrictive ventilatory defects (RVDs) and 23.6% had obstructive ventilatory defects. The mean forced expiratory volume in 1 second was 86% ($\sigma = 20\%$) and Tiffeneau ratio was 78 ($\sigma = 10$). The pathologies justifying surgery were 73% tumors and 12% pneumothorax. Fifty-four patients (55%) underwent parenchymal resection, of which 30 (55%) were anatomical resections with: 23 (42.6%) lobectomy, 5 (9.3%) pneumonectomy, and 2 (3.7%) segmentectomy. The approaches were performed using video thoracoscopy in 59 procedures (60%), 37 (37%) using exclusive open surgery, and 3 (3%) using video-assisted open surgery (Table 1). The mean drainage time was 3.9 days, ($\sigma = 3.4$) with a median of 3 days. The mean length of stay was 9.7 days ($\sigma = 5.8$) with a median of 8 days. The mean time between the intervention and EAT was 7.2 days ($\sigma = 4.5$) with a median of 6 days. The mean interval between drainage removal and EAT was 3.3 days ($\sigma = 2.9$) with a median of 2 days. Considering only parenchymal resections, the mean durations were similar, with durations of respectively 3.3 days, 9.3 days, 7.1 days, and 3.7 days.

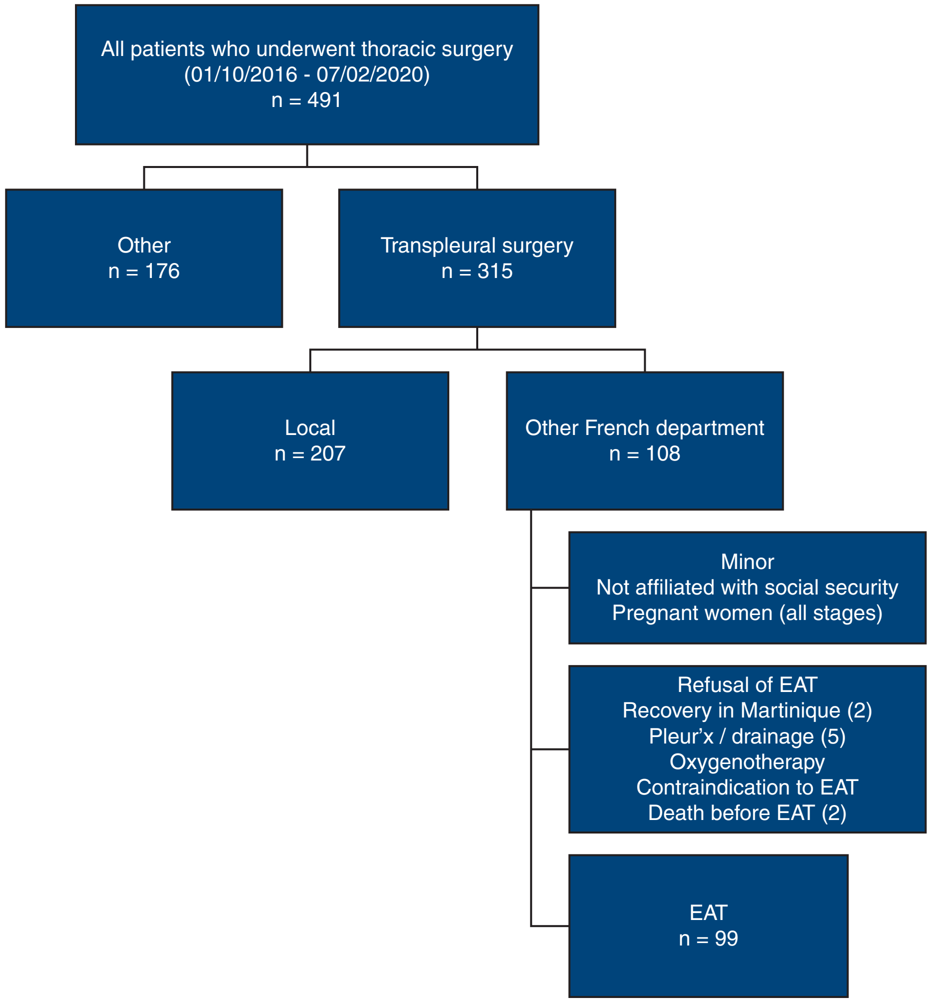

FIGURE 1. Flow chart. Files of all patients (regardless of their geographic origin) operated on for thoracic surgery in the Thoracic and Cardiovascular Surgery Department of the MUH from October 1, 2016, to February 7, 2020, were collected. Among them, transpleural surgical procedures were distinguished from other procedures. The patients who had undergone transpleural surgery, and were proposed for a postoperative EAT (patients originating from a department other than that of Martinique) were selected for our main cohort. The other patients, of Martinican origin, represented the "Local" group and did not travel via airplane within 30 days of the operation. The PleurX™ system helps patients manage recurrent pleural effusions at home. The system includes an indwelling catheter and vacuum bottles that allow patients to drain fluid.

The overall postoperative complication rate was 18%. Before EAT, 89% (n = 16) of the complications were in patients with Clavien–Dindo stage ≤ IIIA and 11% (n = 2) were classified as stage IIIB: these were 2 patients with hemothorax. During or after EAT, only 1 patient reported chest pain and dyspnea with radiological confirmation of a pneumothorax 15 days after the flight. The radiograph performed at landing was normal. The patient did not report any symptoms during the flight. The incidence of EAT-related morbidity after transpleural surgery was 1% (Table 2).

The criteria for concern of an EAT-related pneumothorax were prolonged chest drain bubbling (regarding 3 patients), and residual pneumothorax (regarding 2 patients; 1 treated with exsufflation and the other treated with chest drainage). The average index of prolonged air leak (IPAL) was 3%. Nineteen patients had an IPAL > 5% (moderate to very high risk). Seven patients had an RVD. One combined an RVD with an IPAL > 5. The only patient with a secondary complication to EAT had an IPAL of 17.1 (very high risk) and an obstructive ventilatory defect. He showed no prolonged bubbling nor visible residual pneumothorax. The "EAT" and "Locals" cohorts were statistically comparable, except for the smoking status (P = .01), the cardiac history (P = .004), the type of intervention other than resection (P = .005), the infectious condition justifying surgery (P = .04), and the delay between removal of the last drain and hospital discharge (P = .009), which was 24 hours longer in our EAT cohort (Table 1).

TABLE 1. Patient characteristics in the "EAT" cohort and the "Locals" comparative group

Patient characteristic	EAT (n = 99)	Locals (n = 207)	*P* value
Mean age (SD), years	56.1 (σ = 16.5)	56.9 (σ = 16.9)	.72
Sex			
Male	56 (56)	92 (44)	.09
Female	44 (44)	115 (56)	.09
Mean weight (SD), kg	72.4 (σ = 17.47)	71 (σ = 14.5)	.41
Cardiovascular risk factors			.08
Smoking	47 (47)	54 (26)	.01
Mean pack-years	36	33	
Hypertension	24 (24)	60 (29)	.51
NIDDM	9 (9)	23 (11)	.6
IDDM	4 (4)	4 (2)	.2
Obesity (BMI >30)	14 (14)	22 (11)	.4
Cardiac history	18 (18)	12 (6)	.004
Rythm disorder	4 (22.2)	6 (50)	
Conduction disorder	1 (0.55)	1 (8.3)	
Coronary artery disease	4 (22.2)	1 (8.3)	
Valvulopathy	9 (50)	1 (8.3)	
Other	0	3 (25)	
VTE history	8 (8)	10 (5)	.29
Asbestos exposure	4 (4)	0	NA
Neoplasia history	32 (32)	50 (24)	.25
Cannabis user	5 (5)	4 (2)	.14
Mean preoperative FEV1 (SD)	86 (σ = 20)	83.4 (σ = 20)	.27
Mean preoperative Tiffeneau ratio (SD)	78 (σ = 10)	80.2 (σ = 11)	.18
Pneumological history	38 (38)	56 (27)	.15
OVD	9 (23.6)	NR	
RVD	7 (18.4)	NR	
Other	22 (57.8)	NR	
Type of pathology			
Pneumothorax	12 (12)	30 (14.5)	.27
Tumour	72 (73)	151 (73)	.98
Infectious	9 (9)	7 (3.4)	.04
Inflammatory	0	3 (1.5)	.2
Degenerative	2 (2)	4 (2)	.95
Traumatic	4 (4)	12 (6)	.53
Type of intervention			
Resection	54 (55)	97 (47)	.46
Other, associated or not	45 (45)	110 (53)	.005
Pleural symphisis	21 (46)	66 (60)	
Pleural decortication	7 (15)	7 (6.3)	
Clot removal	1 (2)	4 (3.6)	
Diaphragmatic surgery	5 (11)	11 (10)	
Bronchoplasty	4 (8.8)	0	
Pleural biopsy	16 (35)	55 (50)	
Mediastinal tumor removal	4 (8.8)	13 (11.8)	
Pleural tumor removal	0	2 (1.8)	
Thoracostomy closure	1 (2)	0	
Parietal surgery	2 (4)	2 (1.8)	
Pleuro-pericardial window	2 (4)	0	
Esophageal surgery	0	5 (4.5)	
Thoracic canal surgery	0	1 (0.9)	

(Continued)

TABLE 1. Continued

Patient characteristic	EAT (n = 99)	Locals (n = 207)	*P* value
Type of resection			
Anatomical	30 (55)	55 (57)	.39
Segmentectomy	2 (3.7)	1 (1)	
Lobectomy	23 (42.6)	45 (46.4)	
Bi-lobectomy	0 (0)	4 (4,1)	
Pneumonectomy	5 (9.3)	5 (5.2)	
Nonanatomical	24 (45)	42 (43)	.35
Wedge	23 (42.6)	41 (42.3)	
Bubble resection	1 (1.9)	1 (1)	
Approach			
Videothoracoscopy	59 (60)	138 (67)	.63
Video-assisted surgery	3 (3)	6 (3)	.93
Open surgery	37 (37)	63 (33)	.46
Drainage time, days			
Mean (SD)	3.9 ($\sigma = 3.4$)	3,8 ($\sigma = 3.5$)	.81
Median	3	3	
Average length of stay, days			
Mean (SD)	9.7 ($\sigma = 5.8$)	7.9 ($\sigma = 7.8$)	.06
Median	8	6	
Interval: intervention to EAT, days			
Mean (SD)	7.2 ($\sigma = 4.5$)	6.1 ($\sigma = 5.9$)	.1
Median	6	5	
Interval: drain removal to EAT/discharge, days			
Mean (SD)	3.3 ($\sigma = 2.9$)	2.3 ($\sigma = 2.9$)	.009
Median	2	1	
Hospital discharge with O_2	0	0	NA

Data are expressed as n (%) except where otherwise noted. *EAT*, Early air transport; *SD*, standard deviation; *NIDDM*, non–insulin-dependent diabetes mellitus; *IDDM*, insulin-dependent diabetes mellitus; *BMI*, body mass index; *VTE*, veinous thromboembolism; *FEV1*, forced expiratory volume in 1 second; *OVD*, obstructive ventilatory defect; *NR*, not reported; *RVD*, restrictive ventilatory defect; *NA*, not applicable.

DISCUSSION

The issue of EAT after thoracic surgery is recurrent. Our study result is 1 complication after EAT of 99 unselected patients who underwent transpleural thoracic surgery. The mean drainage time was only 3.9 days ($\sigma = 3.4$) with a median of 3 days, and the mean interval between drainage removal and EAT was only 3.3 days ($\sigma = 2.9$) with a median of 2 days.

Current recommendations are inconsistent (the time frames range from 8 days to 6 weeks[1-5]) and are not on the basis of valid scientific evidence. They are on the basis of a 1999 study[8] involving 12 traumatic pneumothoraces. On the basis of 1 recurrent pneumothorax, the authors concluded that a 14-day delay after radiographic resolution of a traumatic pneumothorax is necessary before flying. The various authorities that published the recommendations extrapolate these conclusions to the postoperative period of a thoracic surgery. A 1-week delay is recommended after removal of the last thoracic drain according to the British Thoracic Society in 2013.[5] Eleven days after a noncomplicated surgery according to the International Air Travel Association in 2018,[4] between 2 and 3 weeks for the Aerospace Medical Association in 2003,[3] and 6 weeks according to the National Health Service (2018 review).[2] In practice, practitioners' attitudes diverge.[6,8] These recommendations are incompatible with local activity. Our recruitment pool was composed of multiple territories scattered throughout the Caribbean arc. AT is used de facto for patients from a territory other than Martinique.

The maximum permitted cabin altitude is 2400 m (for regional, national, or international flights). At this altitude, the atmospheric pressure is lowered to 560 mm Hg (760 mm Hg at sea level).[1] According to the Boyle–Mariotte law (Pressure × Volume/Temperature = Constant), a closed air cavity will increase its volume by 35%. In case of an occult residual pneumothorax (<100 mL according to Plain),[9] EAT will increase the volume of the pneumothorax cavity by 35% (35 mL). The airways are constantly open "from mouth to alveolus" because of their structural properties.[10] This direct communication with the external environment explains the balance between alveolar pressure and atmospheric pressure during each respiratory cycle. This pressure balance limits the volume expansion of the pneumothorax to 35%, while maintaining a negative intrapleural

TABLE 2. Complications according to the Clavien–Dindo classification in the "EAT" cohort and the "Locals" comparative group

Complication and Clavien-Dindo classification	EAT (n = 99)	Locals (n = 207)	*P* value
All	18 (18)	36 (17)	.9
≤IIIa	16 (89)	23 (64)	
IIIb-IV	2 (11)	12 (33.3)	
V	Excluded	1 (2.7)	
Before EAT/discharge	17 (17)	36 (17)	.9
≤IIIa	15 (88)	23 (64)	
IIIb-IV	2 (12)	12 (33.3)	
V	Excluded	1 (2.7)	
During or after EAT	1 (1)	NA	NA
After discharge	NA	0	
≤IIIa	1 (100)	0	
IIIb-IV	0	0	
V	0	0	

Data are expressed as n (%) except where otherwise noted. *EAT*, Early air transport; *NA*, not applicable.

pressure, like that at sea level. Homolateral parenchymal amputation of 35 mL in flight can hardly be responsible for respiratory distress, in case of an O_2 saturation > 92% on the ground, according to the recommendations.[11]

In the case of a pneumonectomy (n = 5), the absence of a "ballooning" cavity on radiograph was sufficient in our cohort to ensure that there were no complications related to EAT. Regarding this subject, the data in the literature are poor. A study, published by the Mayo Clinic, was carried out in 2017.[12] It retrospectively compared the means of transport (ground vs air) used by postoperative patients after undergoing parenchymal resection surgery. The team specifies that it is customary (in their service) to allow a rapid return home of their patients regardless of their mode of transport, in a similar manner to our practices. Of 817 patients operated on for a parenchymal resection between 2005 and 2012, 96 responded that they had traveled via airplane after discharge from hospital, versus 721 who had used ground transportation. Morbidity and mortality were not increased in the AT group: no statistical difference was found in the occurrence of major complications (including pneumothorax), rehospitalization, or the need for new drainage.

Our results are in line with the conclusions of the Mayo Clinic, with a very low incidence of morbidity and mortality. The average time was well below the recommendations, and comparable with those observed in the recent Oregon Health & Science University study on AT after traumatic pneumothorax.[13] The accountability of our only complication to EAT is uncertain (emphysematous patient, at risk of secondary pneumothorax, with a complication that occurred 15 days after the flight, and normal radiograph on landing).

The "EAT" and "Locals" groups were comparable for all criteria (Table 1) except for the 4 mentioned, which were more unfavorable in the "EAT" cohort. The time between the removal of the last chest drain and the EAT was not statistically comparable, with an additional 24 hours in the EAT group. This could be explained by the organization required for this type of transport. Our cohort of EAT patients was comparable with that of the Mayo Clinic, reinforcing our external validity.

The IPAL is a validated score, predictive of the risk of prolonged air leakage in the event of parenchymal resection[14] but it is not a known predictive score for postoperative pneumothorax. The only patient with a complication in our cohort had a very high IPAL (>10).

Our study is limited by its retrospective and monocentric scope, but made up of 99 patients, without loss of follow-up. We relied on criteria reported by our patients during the postoperative consultation, which took place up to 1 month after surgery. It is possible that there might have been paucisymptomatic complications that went unnoticed. Over 1 month, the memorization bias seems to be low. It is not conceivable that there were an insufficient number of cases to observe a statistically significant recurrence rate. Our study, which is comparable in size to that of the Mayo Clinic, is currently the only one that takes into account all transpleural surgeries.

CONCLUSIONS

The development of the thoracic surgery activity in the French West Indies is conditioned by using AT. Our results show a low morbidity of EAT after transpleural surgery. The current data in the literature, the physical laws applied to the respiratory physiology during AT, and the results of our study, all point in the same direction: these are additional arguments in favor of EAT after transpleural surgery, all the while respecting the basic hospital discharge criteria. A chest radiograph free of pneumothorax, and normal vital signs are essential in our opinion to authorize EAT. It would be interesting to study, on a larger scale, the effect of IPAL as an independent risk factor (in case of high IPAL > 10) as well as pathologies that modify transpleural pressures (RVD).

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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