Supplementary

Table S1 Search strategy

MEDLINE (PubMed):

ID	Search	Hits
1	exp pneumothorax/or (pneumothorax* or (lung* adj3 collaps*)).ab,ti,kw.	33,001
2	exp pleurodesis/or (pleurectom* or (pleura* adj3 (excision* or resection*)) or pleurodes* or bullectom* or abrasi* or talca* or (surger* adj3 pneumothora*)).ab,ti,kw.	5,705
3	1 and 2	2,226

EMBASE:

ID	Search	Hits
1	'pneumothorax'/exp OR 'primary spontaneous pneumothorax'/exp OR 'pneumothora*':ti,ab,kw OR ((lung* NEAR/3 collaps*):ti,ab,kw)	66,954
2	'pleurectomy'/exp OR 'pleurodesis'/exp OR 'bullectomy'/exp OR 'abrasion'/exp OR ('pleurectom*' OR (pleura* NEAR/3 (excision* OR resection*)) OR 'pleurodes*' OR 'bullectom*' OR 'abrasi*' OR 'talca*' OR 'talka*' OR (surger* NEAR/3 pneumothora*)):ti,ab,kw	33,428
3	#1 AND #2	4,450
	Conference Abstract	977
	Without Conference Abstract	3,473

Cochrane Library:

ID	Search	Hits
1	MeSH descriptor: [Pneumothorax] explode all trees	319
2	(pneumothora* OR 'lung collaps*'):ti,ab,kw	3,443
3	#1 OR #2	3,443
4	MeSH descriptor: [Pleurodesis] explode all trees	126
5	('pleurectom*' OR 'pleura excision*' OR 'pleural excision*' OR 'pleura resection*' OR 'pleural resection*' OR 'pleurodes*' OR 'bullectom*' OR 'abrasi*' OR 'talca*' OR 'surgery for pneumothorax*'):ti,ab,kw	1,830
6	#4 OR #5	1,830
7	#3 AND #6	1,041
	Reviews	9
	Trials	1,032

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Table S2 Risk of bias assessment per study

Study	Risk of bias tool	Confounding	Selection of participants	Classification of interventions	Deviations from intended interventions	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall
Ayed (2003)	ROBINS-I	n/a	☺	☺	?	☺	☺	☺	☺
Chen (2006)	ROBINS-I	n/a	☺	☺	☺	☺	☺	☺	☺
Rena (2008)	ROBINS-I	n/a	☺	☺	?	😐	☺	☺	😐
Chen (2012)	ROBINS-I	n/a	☺	☺	☺	☺	☺	☺	☺
Min (2014)	ROBINS-I	n/a	☺	☺	😐	☺	☺	☺	😐
Zhang (2017)	ROBINS-I	n/a	☺	☺	☺	☺	😐	☺	😐
Olesen (2018)	ROBINS-I	n/a	☺	☺	☺	☺	☺	☺	☺
Kutluk (2018)	ROBINS-I	n/a	☺	☺	?	☺	😐	☺	😐
Hsu (2021)	ROBINS-I	n/a	☺	☺	☺	☺	☺	☺	☺
Bertrand (1996)	ROBINS-I	n/a	☺	☺	?	☺	😐	☺	😐
Waller (1999)	ROBINS-I	n/a	☺	😐	☹	☺	😐	☺	☹
Ayed (2000)	ROBINS-I	n/a	☺	☺	☺	☺	☺	☺	☺
Horio (2002)	ROBINS-I	n/a	😐	😐	☺	?	☺	☺	😐
Casadio (2002)	ROBINS-I	n/a	☺	☺	☺	?	😐	☺	😐
Lang-Lazdunski (2003)	ROBINS-I	n/a	☹	☺	☹	☺	😐	☺	☹
Gossot (2004)	ROBINS-I	n/a	😐	☺	☺	😐	😐	☺	😐
Chen (2004)	ROBINS-I	n/a	😐	☺	?	?	😐	😐	😐
Ayed (2006)	ROBINS-I	n/a	☺	☺	?	☺	☺	☺	☺
Chang (2006)	ROBINS-I	n/a	☺	☺	?	?	😐	☺	😐
Ben-Nun (2006)	ROBINS-I	n/a	☺	☺	?	☺	😐	☺	😐
Marcheix (2007)	ROBINS-I	n/a	😐	☺	?	?	😐	😐	😐
Cho (2009)	ROBINS-I	n/a	☺	☺	😐	?	☺	☺	😐
Chen (2012)	ROBINS-I	n/a	☺	☺	?	?	😐	☺	😐
Lee (2013)	ROBINS-I	n/a	☺	☺	?	?	😐	☺	😐
Imperatori (2015)	ROBINS-I	n/a	☺	☺	☺	☺	☺	☺	☺
Lin (2016)	ROBINS-I	n/a	☺	☺	?	☺	☺	☺	☺
Dagnegard (2017)	ROBINS-I	n/a	☺	☺	?	☺	😐	☺	😐
Mithiran (2019)	ROBINS-I	n/a	☺	☺	?	☺	☺	☺	☺
Liu (2020)	ROBINS-I	n/a	☺	☺	?	☺	☺	☺	☺
Jeon (2020)	ROBINS-I	n/a	☺	☺	?	?	😐	☺	😐
Jung (2021)	ROBINS-I	n/a	☺	☺	?	?	😐	☺	😐
Kao (2021)	ROBINS-I	n/a	☺	☺	?	☺	😐	☺	😐
Campisi (2022)	ROBINS-I	n/a	😐	☺	?	?	😐	☺	😐
Fung (2022)	ROBINS-I	n/a	😐	☺	?	☺	☺	☺	😐
Huang (2023)	ROBINS-I	n/a	☺	☺	?	☺	😐	☺	😐
Kennedy (2023)	ROBINS-I	n/a	😐	☺	?	?	😐	☺	😐

Risk of bias assessment regarding the primary outcome measure recurrence rate. The ROBINS-1 tool was used to evaluate the cohort studies. Studies with no direct comparison between early and late chest tube management were assessed as single-arm cohort studies irrespective of the initial study design. ☺, low risk of bias; 😐, moderate risk of bias; ☹, high risk of bias; ?, no information; n/a, not applicable.

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Table S3 Summary of findings

Outcomes	Control group: late chest tube removal	Intervention group: early chest tube removal	Number of participants (studies)	Quality or certainty of evidence (GRADE)	Comments
Recurrence rate (% with 95% CI)	4.49 [3.33–6.06]	7.61 [5.44–10.57]	Control group: 4,734 (26 studies); Intervention group: 1,329 (10 studies)	Control group: ⊕⊕◯◯ LOW Intervention group: ⊕⊕◯◯ LOW	The control and intervention group have moderate to serious risk of bias due to lack of comparative RCT's. Also, potential indirectness in both groups
Length of stay (days with 95% CI)	4.83 [4.32–5.39]	4.38 [4.02–4.78]	Control group: 4,196 (22 studies); Intervention group: 1,117 (7 studies)	Control group: ⊕⊕◯◯ LOW Intervention group: ⊕⊕◯◯ LOW	The control and intervention group have moderate to serious risk of bias due to lack of comparative RCT's. Also, potential indirectness. High heterogeneity in both groups.
PAL >5 days (% with 95% CI)	6.12 [4.65–8.01]	4.35 [1.82–10.02]	Control group: 1,672 (8 studies); Intervention group: 115 (2 studies)	Control group: ⊕⊕⊕◯ MODERATE Intervention group: ⊕⊕◯◯ LOW	The control group has possible risk of bias due to lack of comparative RCT's. The intervention groups have small amount of included studies, therefore optimal information size probably not met
Chest tube duration (days with 95% CI)	3.42 [3.08–3.81]	2.50 [2.31–2.71]	Control group: 4,004 (20 studies); Intervention group: 650 (5 studies)	Control group: ⊕⊕◯◯ LOW Intervention group: ⊕⊕◯◯ LOW	The control and intervention group have moderate to serious risk of bias due to lack of comparative RCT's. Also, high heterogeneity in both groups

Postoperative chest tube management after video-assisted thoracoscopic surgery (VATS) for primary spontaneous pneumothorax. Population: patients undergoing VATS pleurodesis for primary spontaneous pneumothorax. Setting: academic and non-academic hospitals. Intervention: early chest tube removal; removal when cessation of air leakage. Comparator: late chest tube removal; removal after a fixed time period and/or pleural fluid production <200 mL/24 hours.

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Table S4 Table of evidence (GRADE system)
Evidence profile: Chest tube management for patients undergoing VATS pleurodesis for PSP

Table S4.1 Late chest tube removal

Outcomes	Limitations	Inconsistency/Heterogeneity	Indirectness	Imprecision	Publication bias	Mean [95% CI]	Number of participants (studies)	Quality or certainty of evidence (GRADE)
Recurrence rate (%)	All studies are (assessed as) cohort studies. The majority was scored as median risk of bias. Downgrade 1 level	I^2 66%. There is some variation in study population due to different inclusion criteria per study. Also, the different surgical and chest tube interventions used may contribute to inconsistency between groups	Potential indirectness, due to differences in interventions or outcomes which are sufficient to make a difference in the outcome. Downgrade 1 level	Not detected, Optimal information size criteria probably met (large sample size), small CI and 95% CI excludes no effect (excludes 1.0)	Not detected	4.49 [3.33–6.06]	N=4,734 (40 groups; 26 studies)	⊕⊕◯◯ LOW
Length of stay (days)	All studies are (assessed as) cohort studies. The majority was scored as median risk of bias. Downgrade 1 level	I^2 99%. There is some variation in study population due to different inclusion criteria per study. Also, Inconsistency can be explained by variation in used interventions between groups and variation in study quality and methodology. No downgrading	Potential indirectness, due to differences in interventions or outcomes which are sufficient to make a difference in the outcome. Downgrade 1 level	Not detected	Not detected	4.83 [4.32–5.39]	N=4,196 (35 groups; 22 studies)	⊕⊕◯◯ LOW
PAL >5 days (%)	All studies are (assessed as) cohort studies. The majority was scored as median risk of bias. Downgrade 1 level	I^2 48%	Not detected	Not detected	Not detected	6.12 [4.65–8.01]	N=1,672 (14 groups; 8 studies)	⊕⊕⊕◯ MODERATE
Chest tube duration (days with 95% CI)	All studies are (assessed as) cohort studies. The majority was scored as median risk of bias. Downgrade 1 level	I^2 98%. There is some variation in study population due to different inclusion criteria per study. Also, Inconsistency can be explained by variation in used interventions between groups and variation in study quality and methodology. No downgrading	Potential indirectness, due to differences in intervention and underlying cause are sufficient to make a difference in the outcome. Downgrade 1 level	Not detected	Not detected	3.42 [3.08–3.81]	N=4,004 (33 groups; 20 studies)	⊕⊕◯◯ LOW

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Table S4.2 Early chest tube removal

Outcomes	Limitations	Inconsistency/ heterogeneity	Indirectness	Imprecision	Publication bias	Mean [95% CI]	Number of participants (studies)	Quality or certainty of evidence (GRADE)
Recurrence rate (%)	All studies are (assessed as) cohort studies. The majority was scored as median risk of bias. Downgrade 1 level.	I^2 8%. There is some variation in study population due to different inclusion criteria per study. The different surgical and chest tube interventions used may contribute to inconsistency between groups	Potential indirectness, due to differences in interventions or outcomes which are sufficient to make a difference in the outcome. Downgrade 1 level	Not detected, Optimal information size criteria probably met (large sample size), small CI and 95% CI excludes no effect (excludes 1.0)	Not detected	7.61 [5.44–10.57]	N= 1,329 (18 groups; 10 studies)	⊕⊕◯◯ LOW
Length of stay (days)	All studies are (assessed as) cohort studies. The majority was scored as median risk of bias. Downgrade 1 level	I^2 98%. There is some variation in study population due to different inclusion criteria per study. Inconsistency can be explained by variation in used interventions between groups and variation in study quality and methodology. Most studies described the same chest tube policy. No downgrading	Potential indirectness, due to differences in interventions or outcomes which are sufficient to make a difference in the outcome. Downgrade 1 level	Not detected	Not detected	4.38 [4.02–4.78]	N=1,117 (13 groups; 7 studies)	⊕⊕◯◯ LOW
PAL >5 days (%)	All studies are (assessed as) cohort studies and scored as median risk of bias. Downgrade 1 level	I^2 0%. Inconsistency can be explained by variation in used interventions between groups and variation in study quality and methodology. No downgrading	Not detected	Possible imprecision due to small sample size with only 2 studies. Optimal information size probably not met. Downgrade 1 level	Not detected	4.35 [1.82–10.02]	N=115 (3 groups; 2 studies)	⊕⊕◯◯ LOW
Chest tube duration (days with 95% CI)	All studies are (assessed as) cohort studies. The majority was scored as median risk of bias. Downgrade 1 level	I^2 98%. There is some variation in study population due to different inclusion criteria per study. Inconsistency can be explained by variation in used interventions between groups and variation in study quality and methodology. Most studies described the same chest tube policy. No downgrading	Potential indirectness, due to differences in interventions or outcomes which are sufficient to make a difference in the outcome. Downgrade 1 level	Not detected	Not detected	2.50 [2.31–2.71]	N=650 (7 groups; 5 studies)	⊕⊕◯◯ LOW

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Table S5 Study details to define all study groups regarding study intervention and applied chest tube management

Study [study group]	n	Study intervention	Details of chest tube management
Late chest tube removal			
Bertrand 1996 [1]	163	Bullectomy + pleural abrasion	Suction was continued for at least 3 days. Chest tube removal when no air leakage and a control chest x-ray showed no residual pneumothorax
Waller 1999 [1]	118	Bullectomy + pleurectomy	Chest tube removal when no air leakage after 24 hours of suction
Ayed 2000 [1]	39	Bullectomy + pleural abrasion	Chest tube removal when full lung expansion, no air leakage and <100 mL pleural fluid/24 h
Ayed 2000 [2]	33	Bullectomy + pleurectomy	Chest tube removal when full lung expansion, no air leakage and <100 mL pleural fluid/24 h
Ayed 2003 [1]	50	Bullectomy + pleurectomy; chest tube on waterseal	Chest tube removal when full lung expansion, no air leakage and <100 mL pleural fluid/24 h
Ayed 2003 [2]	50	Bullectomy + pleurectomy; chest tube on suction	Chest tube removal when full lung expansion, no air leakage and <100 mL pleural fluid/24 h
Lang-Lazdunski 2003 [1]	182	Bullectomy + pleural abrasion	Chest tube removal after 4–5 days when full lung expansion, no air leakage and <100 mL pleural fluid/24 h
Gossot 2004 [1]	185	Bullectomy + pleural abrasion	Chest tube removal when full lung expansion on chest X-ray, no air leakage and <50–100 mL pleural fluid/24 h with minimal fluctuation of fluid level in the chest tube on coughing or deep breathing
Chen 2004 [1]	313	Bullectomy + pleural abrasion and chemical; minocycline	Chest tube removal when full lung expansion and no air leakage for 24 hours
Chen 2004 [2]	51	Bullectomy + pleural abrasion	Chest tube removal when full lung expansion and no air leakage for 24 hours
Ayed 2006 [1]	94	Bullectomy + pleurectomy; macroscopic and histological findings	Chest tube removal when full lung expansion, no air leakage and <100 mL pleural fluid/24 h
Ben-Nun 2006 [1]	58	Bullectomy + pleural abrasion	Chest tube removal when full lung expansion on chest X-ray and no air leakage for 24 hours
Chang 2006 [1]	30	Bullectomy + pleurectomy	Chest tube removal when full lung expansion and no air leakage for 24 hours
Chang 2006 [2]	35	Bullectomy + pleural abrasion	Chest tube removal when full lung expansion and no air leakage for 24 hours
Chen 2006 [1]	103	Bullectomy + pleural abrasion and chemical; minocycline	Chest tube removal when full lung expansion and no air leakage for 24 hours
Chen 2006 [2]	99	Bullectomy + pleural abrasion	Chest tube removal when full lung expansion and no air leakage for 24 hours
Marcheix 2007 [1]	603	Bullectomy + chemical; silver nitrate	Chest tube removal when good pleural apposition, no air leakage and pleural fluid <150 mL/24 h
Rena 2008 [1]	112	Bullectomy + pleural abrasion	Chest tube removal when full lung expansion, no air leakage and pleural fluid <100 mL/24 h
Rena 2008 [2]	108	Bullectomy + pleurectomy	Chest tube removal when full lung expansion, no air leakage and pleural fluid <100 mL/24 h
Cho 2009 [1]	99	Bullectomy + pleural abrasion and covering procedure after wedge resection	Chest tube removal when full lung expansion, no air leakage and pleural fluid <100 mL/24 h. Discharge the day after removal when on chest X-ray no signs of pneumothorax
Chen 2012 [1]	80	Bullectomy + pleurectomy	Chest tube removal when full lung expansion and no air leakage for 24 hours
Chen 2012 [2]	80	Bullectomy + pleural abrasion and chemical; minocycline	Chest tube removal when full lung expansion and no air leakage for 24 hours
Lee 2013 [1]	128	Bullectomy + pleural abrasion	Chest tube removal on postoperative day 1 when full lung expansion on chest X-ray and no air leakage. In patients with air leak, the chest tube was removed the day after confirmation of no air leak.
Lee 2013 [2]	129	Bullectomy + pleural abrasion with PGA sheets	Chest tube removal on postoperative day 1 when full lung expansion on chest X-ray and no air leakage. In patients with air leak, the chest tube was removed the day after confirmation of no air leak.
Min 2014 [1]	145	Bullectomy + pleural abrasion	Chest tube removal when full lung expansion, no air leakage for 24 hours and pleural fluid <100 mL/24 h
Imperatori 2015 [1]	134	Bullectomy + pleurectomy	Chest tube removal on postoperative day 6 when no air leakage
Lin 2016 [1]	112	Bullectomy + pleural abrasion and chemical, iodopovidone; transareolar VATS	Chest tube removal when full lung expansion without pleural effusion on chest X-ray, no air leakage and pleural fluid <100 mL/24 h
Dagnegard 2017 [1]	234	Bullectomy + pleurectomy	Suction for at least 72 hours. Chest tube removal when no air leakage and full lung expansion on chest X-ray after clamping the tube for 4
Zhang 2017 [1]	60	Bullectomy + pleural abrasion with polyglycolic acid sleeve	Chest tube removal when full lung expansion on chest X-ray, no air leakage and clear pleural fluid <200 mL/24 h
Zhang 2017 [2]	74	Bullectomy + pleural abrasion without polyglycolic acid sleeve	Chest tube removal when full lung expansion on chest X-ray, no air leakage and clear pleural fluid <200 mL/24 h
Mithiran 2019 [1]	75	Bullectomy + chemical; magnesium silicate	Chest tube removal when no air leakage and pleural fluid <100 mL/24 h. Discharge on the same or next day
Mithiran 2019 [2]	127	Bullectomy + pleurectomy	Chest tube removal when no air leakage and pleural fluid <100 mL/24 h. Discharge on the same or next day
Hsu 2021 [1]	102	Bullectomy + pleural abrasion with vicryl mesh coverage	Chest tube removal when full lung expansion and no air leakage for 24 hours
Hsu 2021 [2]	102	Bullectomy + pleural abrasion	Chest tube removal when full lung expansion and no air leakage for 24 hours
Campisi 2022 [1]	53	Pleural abrasion	Suction for 48 hours. Chest tube removal when pleural fluid <450 mL/24 h and no air leak.
Campisi 2022 [2]	452	Bullectomy + pleural abrasion with standard apical resection	Suction for 48 hours. Chest tube removal when pleural fluid <450 mL/24 h and no air leak.
Huang 2023 [1]	20	Bullectomy + pleural abrasion and chemical; OK-432	Chest tube removal when full lung expansion or pneumothorax <20% and no air leakage for 24 hours
Huang 2023 [2]	28	Bullectomy + pleural abrasion	Chest tube removal when full lung expansion or pneumothorax <20% and no air leakage for 24 hours
Kennedy 2023 [1]	114	Chemical; talc	Suction for 24 hours, then 48 hours waterseal
Kennedy 2023 [2]	63	Bullectomy + chemical; talc	Suction for 24 hours, then 48 hours waterseal
Early chest tube removal			
Horio 2002 [1]	53	Bullectomy + pleural abrasion	Chest tube removal when neither postoperative bleeding nor air leakage could be observed, and the volume fluid being drained was <300 mL/24 h
Casadio 2002 [1]	133	Bullectomy + pleural abrasion	Chest tube removal when full lung expansion on chest X-ray and no air leakage
Chen 2012 [1]	36	Bullectomy + pleural abrasion; 1 port VATS	Chest tube removal when no air leakage and no bloody fluid drainage
Chen 2012 [2]	26	Bullectomy + pleural abrasion; 3 port VATS	Chest tube removal when no air leakage and no bloody fluid drainage
Kutluk 2018 [1]	45	Bullectomy + pleurectomy; 1 port VATS	Chest tube removal when full lung expansion and no air leakage
Kutluk 2018 [2]	45	Bullectomy + pleurectomy; 2 port VATS	Chest tube removal when full lung expansion and no air leakage
Kutluk 2018 [3]	45	Bullectomy + pleurectomy; 3 port VATS	Chest tube removal when full lung expansion and no air leakage
Olesen 2018 [1]	38	Bullectomy + pleurectomy after HRCT blebs <1 cm	Chest tube removal when no air leakage and clear pleural fluid <250 mL/24 h
Olesen 2018 [2]	50	Bullectomy + pleurectomy after HRCT blebs >1 cm	Chest tube removal when no air leakage and clear pleural fluid <250 mL/24 h
Liu 2020 [1]	142	Bullectomy + pleural abrasion; ipsilateral VATS without contralateral bullae	Chest tube removal when no air leakage and clear pleural fluid drainage
Liu 2020 [2]	123	Bullectomy + pleural abrasion; ipsilateral VATS with contralateral bullae	Chest tube removal when no air leakage and clear pleural fluid drainage
Liu 2020 [3]	70	Bullectomy + pleural abrasion; bilateral VATS with contralateral bullae	Chest tube removal when no air leakage and clear pleural fluid drainage
Jeon 2020 [1]	154	Bullectomy + pleural abrasion	Chest tube removal when no air leakage regardless of the presence of residual pleural cavity and diaphragmatic tenting.
Jung 2021 [1]	175	Bullectomy + chemical; viscum album extract	Chest tube removal when full lung expansion on chest X-ray and no air leakage
Kao 2021 [1]	32	Bullectomy + pleural abrasion; bilateral VATS with contralateral bullae	Chest tube removal when no air leakage and clear pleural fluid drainage
Kao 2021 [2]	40	Bullectomy + pleural abrasion; unilateral VATS with contralateral bullae	Chest tube removal when no air leakage and clear pleural fluid drainage
Kao 2021 [3]	60	Bullectomy + pleural abrasion; unilateral VATS without contralateral bullae	Chest tube removal when no air leakage and clear pleural fluid drainage
Fung 2022 [1]	62	Bullectomy + pleurectomy	Chest tube removal when no clinical signs of air leak and pleural fluid <200 mL after 24 h

VATS, video assisted thoracoscopic surgery; PGA sheet, polyglycolic acid sheet.

Table S6 Outcome measures per included study

Study [study group]†	Recurrence (%)	N follow up	Follow-up (months),mean (SD)	Length of stay (days), mean (SD)
Late chest tube removal				
Bertrand 1996 [1]	4.0	149	24.5 (10.0)	6.9 (3.0)
Waller 1999 [1]	2.5	118	At least 12.0	–
Ayed 2000 [1]	10.3	39	42.0 (range 36.0–54.0)	4.5 (2.1)
Ayed 2000 [2]	0.0	33	42.0 (range 36.0–54.0)	4.1 (1.0)
Ayed 2003 [1]	0.0	50	48.0 (range 30.0–60.0)	3.7 (1.1)
Ayed 2003 [2]	4.0	50	48.0 (range 30.0–60.0)	3.8 (2.1)
Lang-Lazdunski 2003 [1]	9.9	182	24.0 (-)	7.7 (1.6)
Gossot 2004 [1]	3.6	111	36.5 (range 1.0–135.0)	–
Chen 2004 [1]	2.9	313	39 (range 1.0–120.0)	5.8 (3.7)
Chen 2004 [2]	9.8	51	39 (range 1.0–120.0)	7.7 (3.2)
Ayed 2006 [1]	3.2	94	48.0 (range 30.0–60.0)	3.3 (2.0)
Ben-Nun 2006 [1]	3.5	58	46.0 (range 36.0–58.0)	5.0 (1.8)
Chang 2006 [1]	0.0	30	31.2 (5.3)	3.9 (1.7)
Chang 2006 [2]	8.6	35	19.4 (3.2)	3.8 (1.5)
Chen 2006 [1]	1.9	103	29.9 (7.0)	4.0 (1.6)
Chen 2006 [2]	8.1	99	28.3 (6.4)	4.3 (2.8)
Marcheix 2007 [1]	2.0	603	36.5 (28.7)	8.0 (5.4)
Rena 2008 [1]	6.3	112	46.0 (range 24.0–66.0)	3.5 (1.6)
Rena 2008 [2]	4.6	108	46.0 (range 24.0–60.0)	3.9 (1.7)
Cho 2009 [1]	4.0	99	28.8 (6.0)	3.5 (1.8)
Chen 2012 [1]	5.0	80	25.5 (range 12.0–51.0)	3.6 (1.2)
Chen 2012 [2]	3.8	80	26.9 (range 12.0–50.0)	3.6 (1.3)
Lee 2013 [1]	11.7	128	24.0 (4.1)	4.0 (1.8)
Lee 2013 [2]	3.9	129	24.0 (4.1)	4.1 (2.8)
Min 2014 [1]	5.5	145	18.0 (range 6.0–24.0)	10.0 (4.0)
Imperatori 2015 [1]	6.7	134	Median 79.0 (IQR 36.0–187.0)	–
Lin 2016 [1]	0.0	112	15.6 (3.2)	–
Dagnegard 2017 [1]	13.3	234	55.2 (–)	–
Zhang 2017 [1]	0.0	60	15.6 (5.1)	4.0 (1.0)
Zhang 2017 [2]	0.0	74	16.6 (4.8)	4.5 (1.2)
Mithiran 2019 [1]	6.7	75	At least 12.0	5.3 (3.1)
Mithiran 2019 [2]	7.9	127	At least 12.0	5.3 (2.0)
Hsu 2021 [1]	4.9	102	26.2 (11.3)	4.1 (1.7)
Hsu 2021 [2]	16.7	102	26.2 (11.3)	3.8 (1.6)
Campisi 2022 [1]	15.1	53	Median 93.5 (IQR 64.0–123.8)	6.9 (4.5)
Campisi 2022 [2]	6.6	452	Median 93.5 (IQR 64.0–123.8)	5.5 (2.7)
Huang 2023 [1]	5.0	20	18.1 (19.1)	5.6 (1.9)
Huang 2023 [2]	28.6	28	18.1 (19.1)	5.2 (1.7)
Kennedy 2023 [1]	0.9	114	Median 48.0	–
Kennedy 2023 [2]	0.0	63	Median 38.9	–
Early chest tube removal				
Horio 2002 [1]	1.9	53	38.0 (range 26.0–49.0)	3.9 (1.3)
Casadio 2002 [1]	3.8	133	52.8 (17.3)	–
Chen 2012 [1]	2.8	36	16.3 (-)	–
Chen 2012 [2]	7.7	26	30.5 (-)	–
Kutluk 2018 [1]	8.9	45	At least 6.0	3.7 (0.2)
Kutluk 2018 [2]	8.9	45	At least 6.0	3.8 (0.2)
Kutluk 2018 [3]	13.3	45	At least 6.0	4.5 (0.4)
Olesen 2018 [1]	13.2	38	52.3 (24.5)	–
Olesen 2018 [2]	12.0	50	60.8 (25.9)	–
Liu 2020 [1]	8.5	142	73.1 (33.0)	5.6 (2.4)
Liu 2020 [2]	8.1	123	Median 77.0 (IQR 40.0–97.0)	5.5 (2.4)
Liu 2020 [3]	7.1	70	78.6 (35.6)	7.1 (3.1)
Jeon 2020 [1]	13.0	154	51.7 (7.9)	–
Jung 2021 [1]	0.0	175	Median 38.0 (IQR 15.0–48.0)	–
Kao 2021 [1]	9.4	32	95.9 (36.5)	6.0 (1.6)
Kao 2021 [2]	15.0	40	58.5 (73.0)	–
Kao 2021 [3]	16.7	60	82.1 (42.5)	5.0 (1.5)
Fung 2022 [1]	9.7	62	Median 76.5 (range 1.0–155.0)	–

†, definitions of study groups 1, 2, 3 can be found in *Table S5*. SD, standard deviation; IQR, interquartile range.

Study or Subgroup	Mean	SD	Total	Weight	Mean [95% CI]
Late chest tube removal					
Waller 1999 (1)	4.00	.	118	0.0%	4.00
Chen 2004 (1)	5.80	3.70	313	2.1%	5.80 [5.40; 6.22]
Chen 2004 (2)	7.70	3.20	51	2.1%	7.70 [6.87; 8.63]
Ben-Nun 2006 (1)	5.00	1.80	58	2.1%	5.00 [4.56; 5.49]
Chang 2006 (1)	3.90	1.70	30	2.0%	3.90 [3.34; 4.56]
Chang 2006 (2)	3.80	1.50	35	2.0%	3.80 [3.33; 4.33]
Chen 2006 (1)	4.00	1.60	103	2.1%	4.00 [3.70; 4.32]
Chen 2006 (2)	4.30	2.80	99	2.0%	4.30 [3.78; 4.89]
Chen 2012 (1)	3.60	1.20	80	2.1%	3.60 [3.35; 3.87]
Chen 2012 (2)	3.60	1.30	80	2.1%	3.60 [3.33; 3.90]
Lee 2013 (1)	4.00	1.80	128	2.1%	4.00 [3.70; 4.32]
Lee 2013 (2)	4.10	2.80	129	2.1%	4.10 [3.64; 4.61]
Hsu 2021 (1)	4.10	1.70	102	2.1%	4.10 [3.78; 4.44]
Hsu 2021 (2)	3.80	1.60	102	2.1%	3.80 [3.50; 4.12]
Huang 2023 (1)	5.60	1.90	20	2.0%	5.60 [4.83; 6.50]
Huang 2023 (2)	5.20	1.70	28	2.0%	5.20 [4.61; 5.87]
Bertrand 1996 (1)	6.90	3.00	163	2.1%	6.90 [6.45; 7.38]
Ayed 2000 (1)	4.50	2.10	39	2.0%	4.50 [3.89; 5.21]
Ayed 2000 (2)	4.10	1.00	33	2.1%	4.10 [3.77; 4.46]
Ayed 2003 (1)	3.70	1.10	50	2.1%	3.70 [3.41; 4.02]
Ayed 2003 (2)	3.80	2.10	50	2.0%	3.80 [3.26; 4.43]
Lang-Lazdunski 2003 (1)	7.70	1.60	182	2.1%	7.70 [7.47; 7.94]
Gossot 2004 (1)	5.10	2.77	185	2.1%	5.10 [4.72; 5.51]
Ayed 2006 (1)	3.30	2.00	94	2.0%	3.30 [2.92; 3.73]
Marcheix 2007 (1)	8.00	5.40	603	2.1%	8.00 [7.58; 8.44]
Rena 2008 (1)	3.50	1.60	112	2.1%	3.50 [3.22; 3.81]
Rena 2008 (2)	3.90	1.70	108	2.1%	3.90 [3.59; 4.23]
Cho 2009 (1)	3.50	1.80	99	2.1%	3.50 [3.16; 3.87]
Min 2014 (1)	10.00	4.00	145	2.1%	10.00 [9.37; 10.67]
Imperatori 2015 (1)	8.78	4.04	134	2.1%	8.78 [8.13; 9.49]
Lin 2016 (1)	.	.	112	0.0%	
Dagnegard 2017 (1)	.	.	234	0.0%	
Zhang 2017 (1)	4.00	1.00	60	2.1%	4.00 [3.75; 4.26]
Zhang 2017 (2)	4.50	1.20	74	2.1%	4.50 [4.23; 4.78]
Mithiran 2019 (1)	5.30	3.10	75	2.0%	5.30 [4.64; 6.05]
Mithiran 2019 (2)	5.30	2.00	127	2.1%	5.30 [4.96; 5.66]
Campisi 2022 (1)	6.90	4.50	53	1.9%	6.90 [5.79; 8.22]
Campisi 2022 (2)	5.50	2.70	452	2.1%	5.50 [5.26; 5.75]
Kennedy 2023 (1)	4.20	.	114	0.0%	4.20
Kennedy 2023 (2)	4.00	.	63	0.0%	4.00
Total (95% CI)			**4837**	**72.6%**	**4.83 [4.32; 5.39]**
Heterogeneity: $Tau^2 = 0.11$; $Chi^2 = 2427.29$, df = 34 (P = 0); $I^2 = 98.6\%$					
Early chest tube removal					
Casadio 2002 (1)	3.42	1.73	133	2.1%	3.42 [3.13; 3.72]
Chen 2012 (1)	4.10	.	36	0.0%	4.10
Chen 2012 (2)	6.20	.	26	0.0%	6.20
Kutluk 2018 (1)	3.70	0.20	45	2.1%	3.70 [3.64; 3.76]
Kutluk 2018 (2)	3.80	0.20	45	2.1%	3.80 [3.74; 3.86]
Kutluk 2018 (3)	4.50	0.40	45	2.1%	4.50 [4.38; 4.62]
Liu 2020 (1)	5.60	2.40	142	2.1%	5.60 [5.22; 6.01]
Liu 2020 (2)	5.50	2.40	123	2.1%	5.50 [5.09; 5.94]
Liu 2020 (3)	7.10	3.10	70	2.1%	7.10 [6.41; 7.86]
Jeon 2020 (1)	3.25	1.51	154	2.1%	3.25 [3.02; 3.50]
Jung 2021 (1)	2.70	1.49	175	2.1%	2.70 [2.49; 2.93]
Kao 2021 (1)	6.00	1.55	32	2.1%	6.00 [5.49; 6.56]
Kao 2021 (2)	4.71	1.53	40	2.1%	4.71 [4.26; 5.21]
Kao 2021 (3)	5.00	1.52	60	2.1%	5.00 [4.63; 5.40]
Horio 2002 (1)	3.90	1.30	53	2.1%	3.90 [3.57; 4.27]
Olesen 2018 (1)	.	.	38	0.0%	
Olesen 2018 (2)	.	.	50	0.0%	
Fung 2022 (1)	.	.	62	0.0%	
Total (95% CI)			**1329**	**27.4%**	**4.38 [4.02; 4.78]**
Heterogeneity: $Tau^2 = 0.02$; $Chi^2 = 729.44$, df = 12 (P < 0.0001); $I^2 = 98.4\%$					
Total (95% CI)			**6166**	**100.0%**	**4.70 [4.34; 5.10]**
Heterogeneity: $Tau^2 = 0.08$; $Chi^2 = 4702.60$, df = 47 (P = 0); $I^2 = 99.0\%$					
Test for subgroup differences: $Chi^2 = 1.81$, df = 1 (P = 0.1780)					

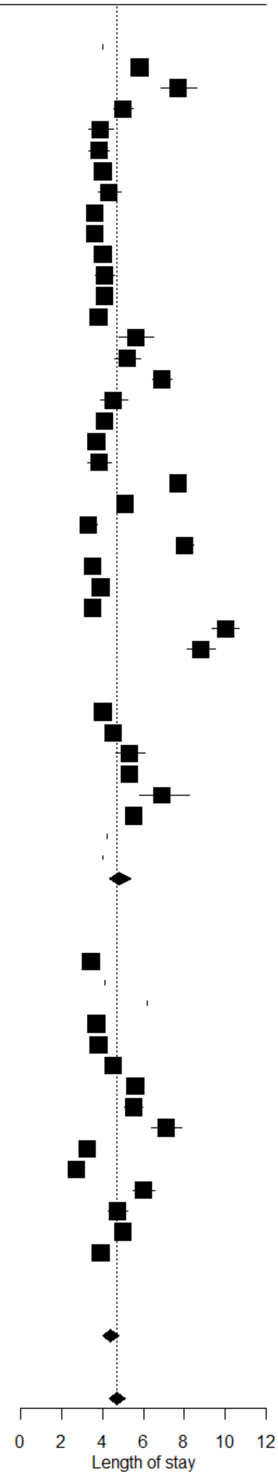

Figure S1 Random effects meta-analysis of mean length of stay in days after VATS bullectomy plus pleurodesis for early and late chest tube removal. Definitions of study groups 1, 2, 3 can be found in *Table S5*. SD, standard deviation; Total, total number of patients; 95% CI, 95% confidence interval; I^2, heterogeneity.

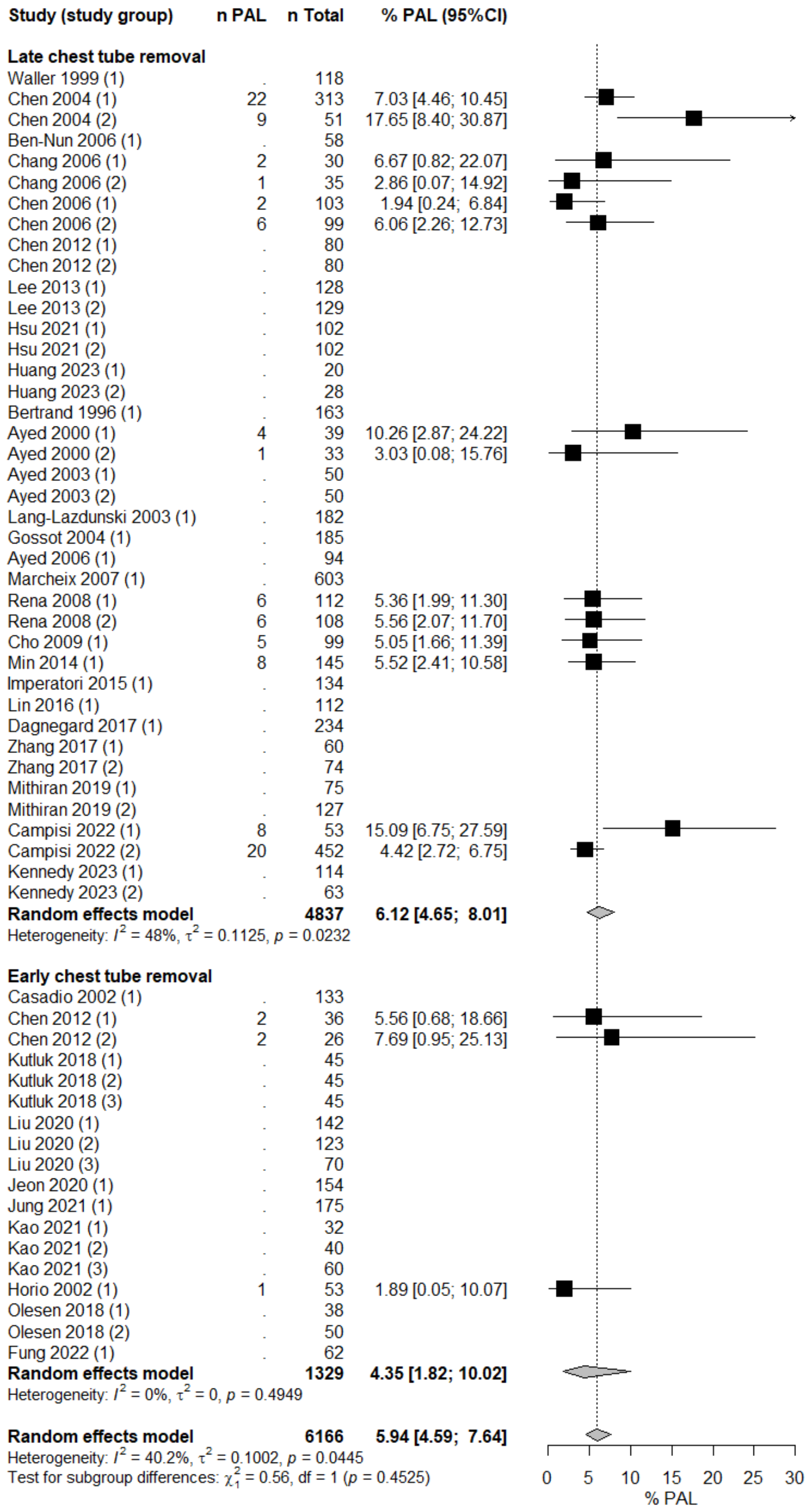

Figure S2 Random Effects Meta-analysis of the risk of prolonged air leakage after VATS bullectomy plus pleurodesis for early and late chest tube removal. Definitions of study groups 1, 2, 3 can be found in *Table S5*. n PAL, number of patients with prolonged air leakage >5 days; n Total, total number of patients; 95% CI, 95% confidence interval; I^2, heterogeneity.

Study or Subgroup	Mean	SD	Total	Weight	Mean [95% CI]
Late chest tube removal					
Waller 1999 (1)	.	.	118	0.0%	
Chen 2004 (1)	4.20	2.90	313	2.6%	4.20 [3.89; 4.53]
Chen 2004 (2)	5.20	2.60	51	2.5%	5.20 [4.53; 5.96]
Ben-Nun 2006 (1)	.	.	58	0.0%	
Chang 2006 (1)	3.20	1.60	30	2.4%	3.20 [2.68; 3.83]
Chang 2006 (2)	3.10	1.10	35	2.5%	3.10 [2.76; 3.49]
Chen 2006 (1)	3.00	1.20	103	2.6%	3.00 [2.78; 3.24]
Chen 2006 (2)	3.00	2.60	99	2.4%	3.00 [2.53; 3.56]
Chen 2012 (1)	2.50	1.10	80	2.5%	2.50 [2.27; 2.75]
Chen 2012 (2)	2.60	1.20	80	2.5%	2.60 [2.35; 2.88]
Lee 2013 (1)	2.70	1.50	128	2.5%	2.70 [2.45; 2.97]
Lee 2013 (2)	2.50	1.90	129	2.5%	2.50 [2.19; 2.85]
Hsu 2021 (1)	2.40	1.80	102	2.4%	2.40 [2.07; 2.78]
Hsu 2021 (2)	2.60	1.60	102	2.5%	2.60 [2.31; 2.93]
Huang 2023 (1)	5.00	1.60	20	2.4%	5.00 [4.35; 5.75]
Huang 2023 (2)	4.60	1.60	28	2.5%	4.60 [4.04; 5.23]
Bertrand 1996 (1)	4.40	1.50	163	2.6%	4.40 [4.18; 4.64]
Ayed 2000 (1)	3.50	2.00	39	2.4%	3.50 [2.93; 4.19]
Ayed 2000 (2)	3.00	1.00	33	2.5%	3.00 [2.68; 3.36]
Ayed 2003 (1)	2.70	1.10	50	2.5%	2.70 [2.41; 3.02]
Ayed 2003 (2)	3.80	2.10	50	2.4%	3.80 [3.26; 4.43]
Lang-Lazdunski 2003 (1)	5.80	1.20	182	2.6%	5.80 [5.63; 5.98]
Gossot 2004 (1)	3.80	2.77	185	2.5%	3.80 [3.42; 4.22]
Ayed 2006 (1)	2.40	1.60	94	2.5%	2.40 [2.10; 2.75]
Marcheix 2007 (1)	5.00	4.00	603	2.6%	5.00 [4.69; 5.33]
Rena 2008 (1)	2.50	1.60	112	2.5%	2.50 [2.22; 2.81]
Rena 2008 (2)	2.90	1.70	108	2.5%	2.90 [2.60; 3.24]
Cho 2009 (1)	1.90	1.80	99	2.3%	1.90 [1.58; 2.29]
Min 2014 (1)	6.00	3.00	145	2.6%	6.00 [5.53; 6.51]
Imperatori 2015 (1)	.	.	134	0.0%	
Lin 2016 (1)	3.60	.	112	0.0%	3.60
Dagnegard 2017 (1)	.	.	234	0.0%	
Zhang 2017 (1)	3.00	0.90	60	2.6%	3.00 [2.78; 3.24]
Zhang 2017 (2)	3.50	1.30	74	2.6%	3.50 [3.22; 3.81]
Mithiran 2019 (1)	4.10	1.30	75	2.6%	4.10 [3.82; 4.41]
Mithiran 2019 (2)	4.50	2.30	127	2.5%	4.50 [4.12; 4.92]
Campisi 2022 (1)	4.10	2.90	53	2.3%	4.10 [3.39; 4.96]
Campisi 2022 (2)	3.90	1.90	452	2.6%	3.90 [3.73; 4.08]
Kennedy 2023 (1)	2.90	.	114	0.0%	2.90
Kennedy 2023 (2)	3.00	.	63	0.0%	3.00
Total (95% CI)			**4837**	**82.3%**	**3.42 [3.08; 3.81]**
Heterogeneity: $Tau^2 = 0.09$; $Chi^2 = 1584.83$, df = 32 ($P < 0.0001$); $I^2 = 98\%$					
Early chest tube removal					
Casadio 2002 (1)	2.42	1.73	133	2.5%	2.42 [2.14; 2.73]
Chen 2012 (1)	.	.	36	0.0%	
Chen 2012 (2)	.	.	26	0.0%	
Kutluk 2018 (1)	3.10	0.20	45	2.6%	3.10 [3.04; 3.16]
Kutluk 2018 (2)	2.70	0.10	45	2.6%	2.70 [2.67; 2.73]
Kutluk 2018 (3)	2.70	0.30	45	2.6%	2.70 [2.61; 2.79]
Liu 2020 (1)	.	.	142	0.0%	
Liu 2020 (2)	.	.	123	0.0%	
Liu 2020 (3)	.	.	70	0.0%	
Jeon 2020 (1)	2.25	1.89	154	2.5%	2.25 [1.97; 2.57]
Jung 2021 (1)	2.35	0.75	175	2.6%	2.35 [2.24; 2.46]
Kao 2021 (1)	.	.	32	0.0%	
Kao 2021 (2)	.	.	40	0.0%	
Kao 2021 (3)	.	.	60	0.0%	
Horio 2002 (1)	1.70	1.10	53	2.4%	1.70 [1.43; 2.02]
Olesen 2018 (1)	.	.	38	0.0%	
Olesen 2018 (2)	.	.	50	0.0%	
Fung 2022 (1)	.	.	62	0.0%	
Total (95% CI)			**1329**	**17.7%**	**2.50 [2.31; 2.71]**
Heterogeneity: $Tau^2 = < 0.01$; $Chi^2 = 251.38$, df = 6 ($P < 0.0001$); $I^2 = 97.6\%$					
Total (95% CI)			**6166**	**100.0%**	**3.22 [2.95; 3.52]**
Heterogeneity: $Tau^2 = 0.08$; $Chi^2 = 3802.96$, df = 39 ($P = 0$); $I^2 = 99.0\%$					
Test for subgroup differences: $Chi^2 = 21.32$, df = 1 ($P < 0.0001$)					

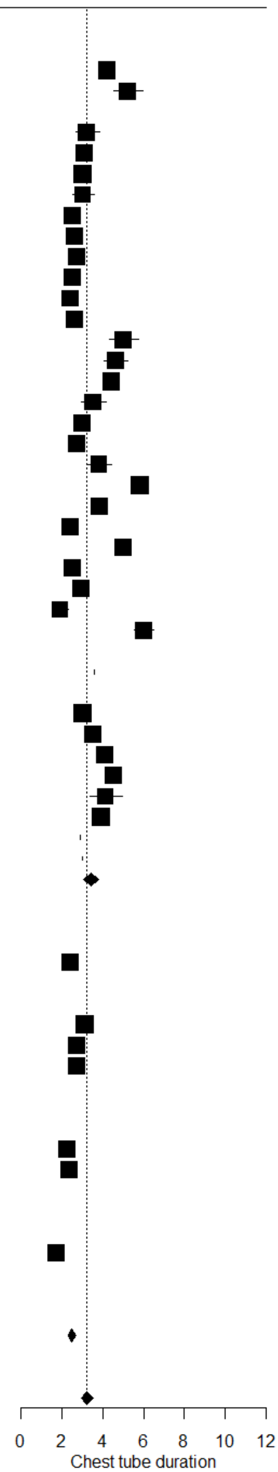

Figure S3 Random effects meta-analysis of mean chest tube duration in days after VATS bullectomy plus pleurodesis for early and late chest tube removal. Definitions of study groups 1, 2, 3 can be found in *Table S5*. SD, standard deviation; Total, total number of patients; 95% CI, 95% confidence interval; I^2, heterogeneity.

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Early chest tube removal

Study (study group)	n Rec	n Total	% Rec (95%CI)
Pleurectomy			
Kutluk 2018 (1)	4	45	8.89 [2.48; 21.22]
Kutluk 2018 (2)	4	45	8.89 [2.48; 21.22]
Kutluk 2018 (3)	6	45	13.33 [5.05; 26.79]
Olesen 2018 (1)	5	38	13.16 [4.41; 28.09]
Olesen 2018 (2)	6	50	12.00 [4.53; 24.31]
Fung 2022 (1)	6	62	9.68 [3.63; 19.88]
Random effects model		**285**	**10.88 [7.75; 15.05]**
Heterogeneity: $I^2 = 0\%$, $\tau^2 = 0$, $p = 0.9627$			
Pleural abrasion			
Casadio 2002 (1)	5	133	3.76 [1.23; 8.56]
Chen 2012 (1)	1	36	2.78 [0.07; 14.53]
Chen 2012 (2)	2	26	7.69 [0.95; 25.13]
Liu 2020 (1)	12	142	8.45 [4.44; 14.30]
Liu 2020 (2)	10	123	8.13 [3.97; 14.44]
Liu 2020 (3)	5	70	7.14 [2.36; 15.89]
Jeon 2020 (1)	20	154	12.99 [8.12; 19.34]
Kao 2021 (1)	3	32	9.38 [1.98; 25.02]
Kao 2021 (2)	6	40	15.00 [5.71; 29.84]
Kao 2021 (3)	10	60	16.67 [8.29; 28.52]
Horio 2002 (1)	1	53	1.89 [0.05; 10.07]
Random effects model		**869**	**8.14 [5.83; 11.25]**
Heterogeneity: $I^2 = 41.6\%$, $\tau^2 = 0.1448$, $p = 0.0715$			
Chemical pleurodesis			
Jung 2021 (1)	0	175	0.00 [0.00; 2.09]
Random effects model		**1329**	**7.61 [5.44; 10.57]**
Heterogeneity: $I^2 = 8.2\%$, $\tau^2 = 0.3499$, $p = 0.3568$			
Test for subgroup differences: $\chi^2_2 = 1.47$, df = 2 ($p = 0.4788$)			

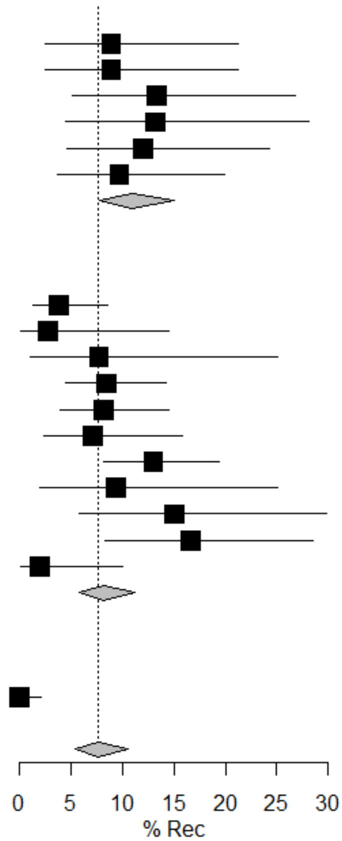

Figure S4 Random effects meta-analysis of the recurrence rate after VATS bullectomy plus pleurodesis per surgical technique for early chest tube removal. Definitions of study groups 1, 2, 3 can be found in *Table S5*. n Rec, number of recurrences; n Total, total number of patients with complete follow-up; 95% CI, 95% confidence interval; I^2, heterogeneity.

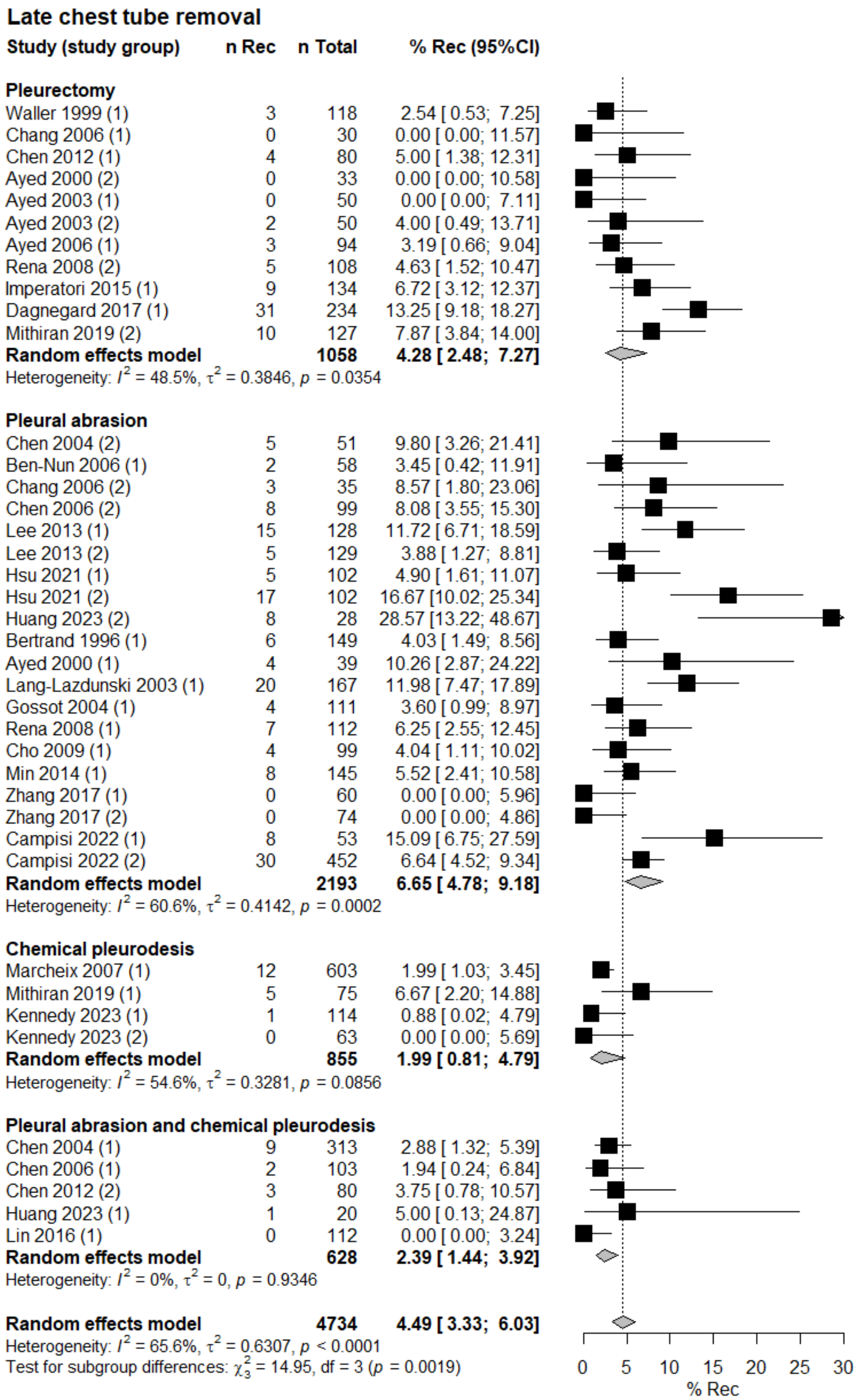

Figure S5 Random effects meta-analysis of the recurrence rate after VATS bullectomy plus pleurodesis per surgical technique for late chest tube removal. Definitions of study groups 1, 2, 3 can be found in *Table S5*. n Rec, number of recurrences; n Total, total number of patients with complete follow-up; 95% CI, 95% confidence interval; I^2, heterogeneity.

 https://dx.doi.org/10.21037/jtd-24-1802

Appendix 1 References of the included studies in this meta-analysis

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