**Table 1** Search strategy (Until December 31st 2023)

|  |  |  |
| --- | --- | --- |
| **Date bases** | **Search strategy** | **Results retrieved** |
| **PubMed** |  |  |
| #1 | ((((thoracoscopic[Title/Abstract]) OR ("Thoracoscopy"[Mesh])) OR (("Thoracic Surgery, Video-Assisted"[Mesh]) OR (((((((((((((Surgeries, Video-Assisted Thoracic[Title/Abstract]) OR (Surgery, Video-Assisted Thoracic[Title/Abstract])) OR (Thoracic Surgeries, Video-Assisted[Title/Abstract])) OR (Thoracic Surgery, Video Assisted[Title/Abstract])) OR (Video-Assisted Thoracic Surgeries[Title/Abstract])) OR (Video-Assisted Thoracoscopic Surgery[Title/Abstract])) OR (Surgeries, Video-Assisted Thoracoscopic[Title/Abstract])) OR (Surgery, Video-Assisted Thoracoscopic[Title/Abstract])) OR (Thoracoscopic Surgeries, Video-Assisted[Title/Abstract])) OR (Thoracoscopic Surgery, Video-Assisted[Title/Abstract])) OR (Video Assisted Thoracoscopic Surgery[Title/Abstract])) OR (VATS[Title/Abstract])) OR (VATSs[Title/Abstract])))) AND (("Recurrence"[Mesh]) OR (((((Recurrences[Title/Abstract]) OR (Recrudescence[Title/Abstract])) OR (Recrudescences[Title/Abstract])) OR (Relapse[Title/Abstract])) OR (Relapses[Title/Abstract])))) AND (("Pneumothorax"[Mesh]) OR (((((((((Spontaneous Pneumothorax[Title/Abstract]) OR (Pneumothorax, Spontaneous[Title/Abstract])) OR (Tension Pneumothorax[Title/Abstract])) OR (Pneumothorax, Tension[Title/Abstract])) OR (Pressure Pneumothorax[Title/Abstract])) OR (Pneumothorax, Pressure[Title/Abstract])) OR (Pneumothorax, Primary Spontaneous[Title/Abstract])) OR (Primary Spontaneous Pneumothorax[Title/Abstract])) OR (Spontaneous Pneumothorax, Primary[Title/Abstract]))) | 633 |
| #2 | ((Recurrence\*[Title/Abstract]) OR (Recrudescence\*[Title/Abstract])) OR (Relapse\*[Title/Abstract]) | 583,470 |
| #3 | Risk Factor\*[Title/Abstract] | 796,449 |
| #4 | #1 AND #2  | 454 |
| #5 | #1 AND #2 AND #3 | 37 |
| **Web of Science** |  |  |
| #1 | ((((TS=(Pneumothorax)) OR TS=(Spontaneous Pneumothorax)) OR TS=(Tension Pneumothorax)) OR TS=(Pressure Pneumothorax)) OR TS=(Primary Spontaneous Pneumothorax) | 12,006 |
| #2 | ((TS=(Recurrence\*)) OR TS=(Recrudescence\*)) OR TS=(Relapse\*) | 438,483 |
| #3 | ((((((TS=(Video-Assisted Thoracoscopic Surgery)) OR TS=(Video-Assisted Thoracic Surgeries)) OR TS=(VATS\*)) OR TS=(Thoracoscopic Surgery)) OR TS=(Thoracoscopic Surgeries)) OR TS=(Thoracic Surgery)) OR TS=(Surgery) | 1,022,521 |
| #4 | TS=(risk factor\*) | 1,172,034 |
| #5 | #1 AND #2 AND #3 | 644 |
| #6 | #1 AND #2 AND #3 AND #4 | 114 |
| **Embase** |  |  |
| #1 | 'pneumothorax'/exp OR 'pneumothorax' | 65,385 |
| #2 | 'video assisted thoracoscopic surgery'/exp OR 'video assisted thoracoscopic surgery' | 19,188 |
| #3 | 'recurrence'/exp OR recurrence OR recurrences OR 'recrudescence'/exp OR recrudescence OR recrudescences OR 'relapse'/exp OR relapse OR relapses | 1,170,283 |
| #4 | 'risk factor'/exp OR 'risk factor' | 1,550,415 |
| #5 | #1 AND #2 AND #3 | 881 |
| #6 | #1 AND #2 AND #3 AND #4 | 76 |
| **Cochrane Library** |  |  |
| #1 | MeSH descriptor: [Pneumothorax] explode all trees | 619 |
| #2 | MeSH descriptor: [Thoracic Surgery, Video-Assisted] explode all trees | 408 |
| #3 | (Recurrence OR Recurrences OR Recrudescence OR Recrudescences OR Relapse OR Relapses): ti, ab, kw (Word variations have been searched)  | 122,816 |
| #4 | (risk factor): ti, ab, kw (Word variations have been searched) | 127,174 |
| #5 | #1 AND #2 AND #3 | 15 |
| #6 | #1 AND #2 AND #3 AND #4 | 3 |

#, designates a history search statement when immediately followed by a number, \*, wildcard symbol for search term truncation.

**Table 2** Quality Appraisal of Case-control studies (Ningbin. Huang and Shi. He)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Study** | **Selection（★）** | **Comparability（★★）** | **Outcome（★）** | **Quality scores** |
| Representativeness of the exposed cohort | Selection of the non exposed cohort | Ascertainment of exposure | Demonstration that outcome of interest was not present at start of study | Comparability of cohorts on the basis of the design or analysis | Assessment of outcome | Was follow-up long enough for outcomes to occur | Adequacy of follow up of cohorts |
| Huang 2007 (27) | ★ | ★ |  | ★ | ★ | ★ | ★ | ★ | 7 |
| Haraguchi 2008 (28) |  | ★ |  | ★ | ★★ | ★ | ★ | ★ | 7 |
| Chang 2015 (29) | ★ | ★ |  | ★ | ★ | ★ | ★ | ★ | 7 |
| Huang 2015 (30) | ★ | ★ |  | ★ | ★ | ★ | ★ | ★ | 7 |
| Ciriaco (31) | ★ | ★ |  | ★ | ★ | ★ | ★ | ★ | 7 |
| Choi (34) | ★ | ★ |  | ★ | ★ | ★ | ★ | ★ | 7 |
| Choi (35) | ★ | ★ |  | ★ | ★ | ★ | ★ | ★ | 7 |
| Asano (36) | ★ | ★ |  | ★ | ★ | ★ | ★ | ★ | 7 |
| Tsuboshima (37) | ★ | ★ |  | ★ | ★★ | ★ | ★ | ★ | 8 |
| Liu (39) | ★ | ★ |  | ★ | ★ | ★ | ★ |  | 6 |
| Jeon (40) | ★ | ★ |  | ★ | ★ | ★ | ★ | ★ | 7 |
| Jeon (41) | ★ | ★ |  | ★ | ★★ | ★ | ★ | ★ | 8 |
| Iwazawa (42) | ★ | ★ |  | ★ | ★ | ★ | ★ | ★ | 7 |
| Shigenobu 2023 (43) | ★ | ★ |  | ★ | ★ | ★ | ★ | ★ | 7 |

★, low risk of bias, ★★, high risk of bias.

**Table 3** Quality Appraisal of cohort studies (Ningbin. Huang and Shi. He)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Study** | **Selection（★）** | **Comparability（★★）** | **Outcome（★）** | **Quality scores** |
| Is the case definition adequate | Representativeness of the cases | Selection of controls | Definition of controls | Comparability of cases and controls on the basis of the design or analysis | Ascertainment of exposure | Same method of ascertainment for cases and controls | Non-response rate |
| Cardillo 2016 (32) | ★ | ★ | ★ | ★ | ★ | ★ | ★ | ★ | 8 |
| Chiu 2017 (33) | ★ | ★ | ★ | ★ | ★★ | ★ | ★ | ★ | 9 |
| Onuki 2019 (38) | ★ | ★ | ★ | ★ | ★★ | ★ | ★ | ★ | 9 |

★, low risk of bias, ★★, high risk of bias

**Table 3** Characteristics of 72 studies

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| First author(Year) | Country | Study type | Sample size, n (M/F) | ORR, % | Age, years  | Height, m | Weight, kg | BMI, kg/m2 | Smoking (Yes/No) | Operation type | Pleurodesis type | Operation side, n (L/R) | Side ofrecurrence,n (L/R) | History of contralateral pneumothorax (Yes/No) | Operation time | POD, day | Follow-up | Time to recurrence |
| Walker 1994 (60) | UK | Randomized Controlled Trial | 15(9/6) | 13.33% | Total: 23(13–38) | NA | NA | NA | NA | Bulla staple, Bulla ligation | Mechanical: Pleurectomy | NA | NA | NA | NA | NA | NA | NA |
| Yim 1995 (61) | China | Retrospective Study | 100(97/3) | 3.00% | NA | NA | NA | NA | NA | Bullectomy, Argon beam coagulation  | Mechanical: Nonabsorbable mesh (Marlex) | NA | NA | NA | Total: 4 (1-30)  | NA | Total: 17 (8-24) months  | NA |
| Ayed 2000 (62) | Kuwait | Retrospective Study | 72(67/5) | 5.56% | Total: 25(15–40) | NA | NA | NA | NA | Bullectomy | Mechanical: Pleurectomy, Pleural abrasion | NA | NA | NA | Total: 56±11 | Total: 4±2 | Total: 42 (36-54) months  | NA |
| Cardillo 2000 (63) | Italy | Retrospective Study | 432(289/143) | 3.70% | NA | NA | NA | NA | NA | Bulla staple, Bulla ligation | Mechanical: PleurectomyChemical: Talc | NA | NA | NA | NA | NA | Total: 38 (2-72) months  | NA |
| Cardillo 2001 (64) | Italy | Retrospective Study | 597 | 3.85% | NA | NA | NA | NA | NA | Bulla staple, Bulla ligation | Mechanical: PleurectomyChemical: Talc | NA | NA | NA | NA | NA | NA | NA |
| Ayed 2003 (65) | Kuwait | Prospective Study | 100(94/6) | 2.00% | Total: 22.9±3.9 | NA | NA | NA | NA | Bullectomy | Mechanical: Gauze, Apical pleurectomy | NA | NA | NA | Total: 53.4±9.3 | NA | Total: 48 (30-60) months | NA |
| Ayed 2006 (66) | Kuwait | Prospective Study | 94(81/13) | 3.19% | Total: 24.6±5.8 | NA | NA | NA | NA | Bullectomy | Mechanical: Apical pleurectomy | NA | NA | NA | Total: 46±7.9 | NA | Total: 48 (30-60) months | NA |
| Chen 2006 (67) | China | Randomized Controlled Trial | 202 | 4.95% | NA | NA | NA | NA | Total: 57/145 | Bullectomy | Mechanical: Pleural abrasionChemical: Minocycline | Total: 105/97 | NA | NA | NA | NA | NA | NA |
| Huang 2007 (68) | China | Case-control Study | 102(95/7) | 6.86% | NA | NA | NA | NA | Total: 45/57 | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Huang 2007 (27) | China | Retrospective Study | 231(215/16) | 14.29% | RG: 20.18±3.66NRG: 22.36±5.63 | RG: 1.75±6.14NRG: 1.74±7.91 | RG: 55.87±7.46NRG: 59.57±7.91 | RG: 18.13±2.02NRG: 19.72±2.16 | RG: 18/15NRG: 98/100 | Bullectomy | Mechanical: Gauze | NA | NA | NA | NA | NA | Total: 7.6 (median) years | NA |
| Bialas 2008 (69) | USA | Retrospective Study | 32(25/7) | 28.13% | Total: 16.5(13–20) | NA | NA | Total: 20.2(16.5–23.7) | NA | Bullectomy | Chemical: Talc | Total: 18/14 | NA | NA | Total: 64.1 (mean) | NA | Total: 46 (6-104) months | NA |
| Cho 2008 (70) | Korea | Retrospective Study | 219(199/20) | 4.85% | Total: 24.3±11.2 | NA | NA | NA | NA | Bullectomy | Mechanical: Fibrin glue and Absorbable mesh | Total: 103/116 | NA | NA | NA | Total: 3.8±1.6 | Total: 36 (median) months | NA |
| Haraguchi 2008 (28) | Japan | Retrospective Study | 62(54/8) | 16.10% | RG: 21.6±5.4NRG: 24.0±7.0 | NA | NA | NA | RG: 2/8NRG: 22/30 | Bullectomy | NA | RG: 6/4NRG: 25/27 | NA | NA | Total:70±32 | Total: 7.5±6.7 | Total: 64 (25-144) months | NA |
| Nakanishi 2009 (71) | Japan | Retrospective Study | 48(44/4) | 25.00% | Total: 28.4±15.6 | NA | NA | NA | NA | Bullectomy | NA | Total: 25/23 | NA | NA | Total: 127.1±66.2 | NA | Total: 43.5±16.1 months | 699±631 days |
| Ryu 2009 (72) | Korea | Retrospective Study | 158 | 7.59% | NA | NA | NA | NA | NA | Bullectomy | Mechanical: Gauze | NA | NA | NA | NA | NA | NA | NA |
| Choi 2013 (73) | Korea | Retrospective Study | 281(250/31) | 6.76% | 19.2 ± 4.0 | NA | NA | NA | Total: 69/212 | Bullectomy | Mechanical: Fibrin glue and Absorbable mesh (PGA), Pleurectomy, Pleural electrocauterization | Total: 138/143 | NA | NA | NA | NA | Total: 47.1±20.5 months | 22.8±16.2 months |
| Chiu 2014 (74) | China | Retrospective Study | 84(74/10) | 21.43% | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Li 2014 (75) | China | Retrospective Study | 180(144/36) | 1.67% | Total: 23(14–54) | NA | NA | NA | NA | Wedge resection | Mechanical: Pleural abrasion | Total: 103/61 | NA | NA | Total: 76 (43-160)  | Total: 5.8 (3-16)  | Total: 57 (24-105) months | NA |
| Chou 2014 (76) | China | Retrospective Study | 239(239/0) | 4.60% | NA | NA | NA | NA | NA | Bullectomy | Mechanical: Nonabsorbable mesh (Marlex) | NA | NA | NA | NA | NA | Total: 36.95 (mean) months | NA |
| Min 2014 (77) | China | Randomized Controlled Trial | 289(260/29) | 5.88% | NA | NA | NA | NA | Total: 54/235 | Wedge resection | Mechanical: Gauze | Total: 151/138 | NA | NA | NA | NA | Total: 18 (6-24) months | NA |
| Lee 2014 (78) | Korea | Randomized Controlled Trial | 1, 414(1, 295/119) | 13.58% | Total: 18(15–35) | NA | NA | NA | Total: 424/990 | Bullectomy | Mechanical: GauzeChemical: Povidone-iodine | Total: 761/652 | NA | NA | NA | NA | Total: 19.5 (0.3-66.7) months | NA |
| Son 2015 (79) | Korea | Retrospective Study | 104(91/13) | 0.96% | Total: 22.7±8.8 | NA | NA | NA | NA | Wedge resection | NA | NA | NA | NA | Total: 49.7±13.9 | Total: 4.8±1.7 | Total: 11±6 months | NA |
| Yamazaki 2015 (80) | Japan | Retrospective Study | 141(113/28) | 2.84% | NA | NA | NA | NA | Total: 54/87 | Wedge resection | Mechanical: Fibrin glue | Total: 67/74 | NA | NA | NA | Total: 4.8±1.8 | Total: 28 (median) years | NA |
| Pompili 2015 (81) | UK | Retrospective Study | 136(107/29) | 7.47% | NA | NA | NA | NA | NA | Wedge resection | NA | Total: 13/62 | NA | NA | NA | Total: 4.8±1.9 | Total: 1 years | NA |
| Chang 2015 (29) | China | Case-control Study | 149(141/17) | 11.40% | RG: 20.7±3.7NRG: 1.73±0.05 | NA | NA | RG: 19.4±1.9NRG: 18.7±2.0 | RG: 1/16NRG: 64/68 | Wedge resection | Mechanical: Gauze, Fibrin glue and Absorbable mesh | RG: 11/6NRG: 64/68 | NA | NA | NA | Total: 4.8±1.10 | RG: 23.9 ± 25.1 monthsNRG: 37.4 ± 26.80 months | 12.1 + 18.6 months |
| Huang 2015 (30) | China  | Case-control Study | 248(226/22) | 4.80% | RG: 17(14–21)NRG: 19(14–38) | RG: 1.71±0.05NRG: 1.73±0.05 | RG: 1.71±0.05NRG: 1.73±0.05 | RG: 17.67±1.78NRG: 18.5±1.82 | RG: 1/11NRG: 28/208 | Wedge resection | Mechanical: GauzeChemical: Povidone-iodine | RG: 6/1NRG: 42/9 | NA | RG: 2/10NRG: 43/193 | NA | Total: 4.8±1.11 | RG: 50.42 ± 13.10 monthsNRG: 50.14 ± 16.30 months | NA |
| Noh 2015 (19) | Korea | Retrospective Study | 285(256/29) | 17.89% | NA | NA | NA | NA | NA | Wedge resection | NA | NA | NA | NA | NA | NA | NA | NA |
| Primavesi 2016 (82) | Austria | Retrospective Study | 33(21/12) | 12.12% | Total: 29 (19–50) | NA | NA | Total: 19.9(16.6–26.1) | Total: 19/14 | Bullectomy | Mechanical: Gauze, Pleurectomy  | Total: 13/20 | NA | NA | NA | NA | Total: 50.5 (18-84.4) years | NA |
| Ciriaco 2016 (31) | Italy | Case-control Study | 58(48/10) | 13.00% | Total: 16.6±1.6 | NA | NA | NA | NA | Bullectomy | Mechanical: Apical pleurectomy | RG: 6/1NRG: 42/9 | NA | NA | NA | NA | NA | NA |
| Herrmann 2016 (16) | Germany | Retrospective Study | 185(129/56) | 2.16% | Total: 32.6 ± 15.5 years | NA | NA | NA | NA | Bullectomy | Mechanical: Pleurectomy  | Total: 56/129 | NA | NA | Total: 57(26-153) | Total: 7 (6-8)  | Total: 70.8±33.5 months | NA |
| Chen 2016 (83) | China | Retrospective Study | 553(504/49) | 34.54% | NA | NA | NA | NA | Total: 306/247 | Wedge resection | Mechanical: Gauze | NA | NA | NA | NA | NA | NA | NA |
| Cardillo 2016 (32) | Italy | Prospective Study | 1, 380(1, 078/337) | 1.90% | Total: 25.3(21.0–29.4) | NA | NA | NA | RG: 24/2NRG:551/803 | Bullectomy, Lobectomy | Chemical: Talc | RG: 12/14NRG:554/826 | NA | NA | NA | NA | Total: 8.5 (4.9-11.9) years | 13 (8-16.5) months |
| Cho 2017 (84) | Korea | Retrospective Study | 25(24/1) | 44.00% | NA | NA | NA | NA | NA | Bullectomy | Mechanical: Fibrin glue and Absorbable mesh, Pleural abrasion | NA | NA | NA | NA | NA | Total: 62.0±32.6 months | NA |
| Chiu 2017 (33) | China | Retrospective Study | 89(77/12) | 51.69% | Total: 21.0±5.2 | RG:1.723±0.73 | RG: 56.3±9.0 | Total: 18.9±2.2 | RG: 6/40NRG: 11/32 | Wedge resection | Mechanical: Pleural abrasion | NA | NA | NA | NA | NA | NA | NA |
| Nakayama 2017 (21) | Japan | Retrospective Study | 167(154/13) | 9.58% | NA | NA | NA | NA | Total: 56/111 | Bullectomy | Mechanical: Fibrin glue and Absorbable mesh (PGA) | Total: 91/76 | NA | Total: 38/129 | NA | NA | Total: 25.8 (3-107) months | 25.8 (3-107) months |
| Dagnegard 2017 (85) | Sweden | Retrospective Study | 234(171/63) | 13.25% | NA | NA | NA | NA | Total: 66/168 | Bullectomy | Mechanical: Pleurectomy  | NA | NA | NA | NA | NA | Total: 4,6 (mean) years | NA |
| Zhang 2017 (86) | China | Retrospective Study | 345(283/62) | 2.90% | Total: 27.32±11.41 | NA | NA | NA | Total: 63/282 | Bullectomy | Mechanical: Pleural abrasion | Total: 180/165 | NA | NA | NA | NA | Total: 47 (1-90) months | NA |
| Cho 2018 (87) | Korea | Case-control Study | 76(70/6) | 0.03% | Total: 18.5(15-35) | NA | NA | NA | NA | Bullectomy | Mechanical: Gauze, Fibrin glue and Absorbable mesh | Total: 44/32 | NA | NA | NA | NA | NA | NA |
| Choi 2018 (34) | Korea | Retrospective Study | 85(75/10) | 24.71% | RG: 17.1±1.2NRG:18.6±3.6 | RG: 1.75±0.06NRG: 1.74±0.08 | RG: 56.2±6.7NRG:56.6±8.4 | RG: 18.2±1.6NRG: 18.6±2.1 | NA | NA | NA | NA | NA | NA | NA | NA | RG: 22.0±23.9 monthsNRG: 25.9±20.0 months | NA |
| Olesen 2018 (14) | Denmark | Randomized Controlled Trial | 88(69/19) | 28.41% | NA | NA | NA | NA | Total: 69/19 | Bullectomy | Mechanical: Pleural abrasion | NA | NA | NA | NA | NA | NA | NA |
| Kutluk 2018 (88) | Turkey | Prospective Study | 135(116/19) | 5.19% | Total: 27.91±9.18 | NA | NA | NA | NA | NA | NA | Total: 66/69 | NA | NA | NA | NA | NA | NA |
| Choi 2018 (35) | Korea | Case-control Study | 360(269/91) | 11.11% | RG: 17.6±2.4NRG: 19.3±3.6 | RG: 175±7NRG: 174±8 | RG: 57.1±7.8NRG: 57.4±9.0 | RG: 18.6±1.9NRG: 18.9±2.3 | NA | Bullectomy | Mechanical: Fibrin glue and Absorbable mesh (PGA)Chemical: Minocycline | RG: 26/14NRG: 173/147 | NA | NA | NA | NA | RG: 50.7±22.8 monthsNRG: 43.7±24.5 months | NA |
| Asano 2019 (36) | Japan | Case-control Study | 192(164/28) | 7.30% | NA | NA | NA | NA | NG: 4/10NRG: 79/99 | Bullectomy | Mechanical: Fibrin glue and Absorbable mesh (PGA)Chemical: Minocycline | NA | NA | NA | NA | NA | NA | 5.5 months (median) |
| Yamanaka 2019 (89) | Japan | Retrospective Study | 66(36/30) | 25.76% | NA | NA | NA | NA | NA | Bullectomy | Mechanical: Fibrin glue and Absorbable mesh (PGA, ORC), Laser | Total: 38/28 | NA | NA | NA | NA | NA | NA |
| Tsuboshima 2019 (37) | Japan | Case-control Study | 91(83/8) | 8.79% | RG: 17(15-34)NGR: 20(14-86) | NA | NA | RG: 18.4(15.7-19.6)NGR: 19.6(14.1-25.1) | RG: 1/7NRG: 25/58 | Bullectomy | Mechanical: Fibrin glue and Absorbable mesh (PGA, ORC) | RG: 2/6NRG: 50/33 | Total: 2/6 | NA | NA | NA | RG: 321.5±169.8 daysNRG: 268.4±223.4 days | 321.5±169.8 days |
| Tsuboshima 2019 (20) | Japan | Case-control Study | 92(84/8) | 16.30% | Total: 18±2.5 | NA | NA | Total: 18.8±1.8 | Total: 80/12 | Bullectomy, Wedge resection | Mechanical: Gauze, Pleurectomy  | NA | NA | Total: 12/80 | NA | NA | NA | 401.5 (16–3,339) days |
| Onuki 2019 (38) | Japan | Prospective Study | 66(60/6) | 13.64% | RG: 17±1.6NRG:17±1.3 | RG: 1.742±0.64NRG: 1.714±0.65 | RG: 56.7±7.0NRG: 56.0±7.3 | RG: 18.6±2.3NRG:19.1±1.8 | NA | Bullectomy | Mechanical: Fibrin glue and Absorbable mesh (PGA)Chemical: Minocycline | RG: 6/3NRG: 32/25 | Total: 6/3 | RG: 7/2NRG: 19/38 | NA | NA | Total: 938±496 days | 869±542 days |
| Mithiran 2019 (90) | Singapore | Retrospective Study | 202(178/24) | 7.43% | NA | NA | NA | NA | Total: 81/121 | Bullectomy | Mechanical: Fibrin glue and Absorbable mesh  | NA | NA | NA | NA | NA | NA | NA |
| Tsuboshima 2019 (91) | Japan | Retrospective Study | 252(227/25) | 17.46% | NA | NA | NA | NA | Total: 152/100 | Bullectomy | Mechanical: Fibrin glue and Absorbable mesh (PGA, ORC) | Total: 138/114 | NA | NA | NA | NA | NA | NA |
| Kim 2020 (92) | Korea | Prospective Study | 59(43/16) | 5.08% | Total: 18(12-50) | NA | NA | NA | Total: 5/59 | Bullectomy | Mechanical: Fibrin glue and Absorbable mesh (PGA) | NA | NA | NA | Total: 41.6±9.5 | NA | Total: 21.5 (2.5-61.4) months | NA |
| Liu 2020 (39) | China | Case-control Study | 335(294/41) | 14.33% | NA | NA | NA | NA | RG: 7/41NRG: 65/222 | Bullectomy | Mechanical: Gauze | NA | NA | NA | NA | NA | Total: 75.0 (50.0-99.0) months | NA |
| Jeon 2020 (40) | Korea | Case-control Study | 154(144/10) | 13.00% | Total: 19 (15-39) | RG: 174.0 (165-181)NRG: 174.7 (149-195) | RG: 56.71 (45-75)NRG: 59.16 (40-82) | RG: 18.98 (15.26-23.94)NRG: 18.99 (15.43-26.47) | RG: 0/20NRG: 36/98 | Bullectomy | Mechanical: Gauze | Total: 79/61 | NA | NA | Total: 35(15-120) | RG: 3.4 (2-9)NRG: 3.2 (2-10) | Total: 52 (28-70) months | NA |
| Fujiwara 2020 (93) | Japan | Retrospective Study | 117 | 13.68% | NA | NA | NA | NA | NA | Bullectomy, Bulla ligation, Pulmorrhaphy | NA | NA | NA | NA | NA | NA | NA | NA |
| Jeon 2020 (41) | Korea | Case-control Study | 276(261/15) | 8.33% | Total: 19 (13-36) | RG: 174.3 (165-185)NRG: 175.3 (148-195) | RG: 55.5 (45-75)NRG: 59.1 (40-82) | RG: 17.92 (15.3-23.9)NRG: 19 (15.2-26.5) | RG: 0/23NRG: 54/199 | Wedge resection | Mechanical: Fibrin glue and Absorbable mesh (PGA), Pleurectomy | NA | NA | NA | Total: 35(15-120) | Total: 4(2-12)af | Total: 50.0 (16.0-79.0) months | 7 (1-72) months |
| Tsuboshima 2020 (94) | Japan | Retrospective Study | 627(521/106) | 9.09% | NA | NA | NA | NA | NA | Bullectomy | Mechanical: Absorbable mesh (PGA, ORC) | Total: 368/259 | NA | NA | NA | NA | NA | NA |
| Cattoni 2020 (95) | Italy | Retrospective Study | 843(673/170) | 9.37% | Total: 22(18-28) | NA | NA | Total: 20(19-22) | Total: 338/505 | Bullectomy | Mechanical: Gauze, Partial pleurectomy, Pleural electrocauterization | NA | NA | NA | NA | NA | Total: 70.0 (66.6-73.4) months | NA |
| Zhu 2021 (96) | China | Retrospective Study | 20(18/2) | 5.00% | Total: 27.25±10.92 | NA | NA | Total: 19.95±2.38 | Total: 8/12 | Wedge resection | Mechanical: Pleural electrocauterization | NA | NA | NA | Total: 48.5±32.38 | NA | Total: 23.45±7.18 months | 5 months |
| Adachi 2021 (97) | Japan | Prospective Study | 25(21/4) | 12.00% | Total: 19(16-25) | NA | NA | NA | NA | Bullectomy | Mechanical: Absorbable mesh (INTEGRAN) | Total: 16/9 | NA | NA | NA | Total: 2 (2-8)af | Total: 367.0(202.0-555.0) days | NA |
| Fung 2021 (98) | Germany | Retrospective Study | 58(48/10) | 12.07% | NA | NA | NA | NA | Total: 12/46 | Wedge resection | Mechanical: Partial pleurectomy  | Total: 21/37 | NA | NA | NA | NA | Total: 61.6(5.0-119.0) months | 61.6 (median) months |
| Kao 2021 (99) | China | Retrospective Study | 132(132/0) | 0.76% | NA | NA | NA | NA | Total: 32/100 | Bullectomy | Mechanical: Nonabsorbable mesh (Marlex) | NA | NA | NA | NA | NA | NA | NA |
| Jung 2021 (100) | Korea | Retrospective Study | 175(170/5) | 0.00% | Total: 20(17-32) | NA | NA | NA | NA | Bullectomy | Mechanical: Absorbable mesh (PGA) | Total: 100/75 | NA | NA | Total: 20 (15-30) | Total: 2 (2-4)af | Total: 38(15.0-48.0) months | NA |
| Hsu 2021 (101) | China | Randomized Controlled Trial | 204(179/25) | 9.31% | NA | NA | NA | NA | Total: 44/160 | Bullectomy | Mechanical: Pleural abrasion,Absorbable mesh(Vicryl) | Total: 116/88 | NA | NA | NA | NA | Total: 26.2 ± 11.3 months | NA |
| Brophy 2021 (102) | Canada | Retrospective Study | 222(161/61) | 12.61% | Total: 26.3±7.9 | NA | NA | NA | Total: 140/82 | Bullectomy | Mechanical: Pleurectomy  | NA | NA | NA | NA | NA | NA | NA |
| Iwazawa 2021 (42) | Japan | Case-control Study | 357(322/35) | 14.00% | Total: 20.9±3.8 | NA | NA | NA | NA | Bullectomy | Mechanical: Absorbable mesh (PGA, ORC) | RG: 29/21NRG: 154/203 | RG: 17/10NRG: 104/76 | RG: 19/31NRG: 91/266 | NA | NA | NA | NA |
| Woo 2021 (103) | Korea | Retrospective Study | 841 | 9.16% | NA | NA | NA | NA | NA | Bullectomy | Mechanical: Gauze, Fibrin glue and Absorbable mesh (PGA) | NA | NA | NA | NA | NA | NA | NA |
| Hung 2021 (15) | China | Retrospective Study | 6654(5928/726) | 24.77% | Total: 23.2±7.8 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | Total: 7.7±4.4 | Total: 6.7±2.2 years | 6.7±2.2 years |
| Fung 2022 (104) | Germany | Retrospective Study | 62(48/14) | 9.68% | Total: 24.6(mean) | Total: 1.8(mean) | Total: 67.1(mean) | Total: 20.7(mean) | Total: 19/43 | Wedge resection | Mechanical: Partial pleurectomy  | NA | NA | NA | Total: 79.4(mean) | Total: 6.1(mean) | NA | NA |
| Shigefuku 2022 (105) | Japan | Retrospective Study | 143(132/11) | 11.19% | NA | NA | NA | NA | Total: 112/31 | NA | NA | Total: 81/62 | NA | Total: 16/127 | NA | NA | NA | NA |
| Oda 2022 (106) | Japan | Retrospective Study | 373(344/29) | 11.80% | NA | NA | NA | NA | Total: 336/37 | Bullectomy | Mechanical: Absorbable mesh (PGA, ORC) | Total: 220/153 | NA | NA | NA | NA | NA | 376(8-1762) days |
| Campisi 2022 (107) | Italy | Retrospective Study | 505(398/207) | 7.34% | NA | NA | NA | NA | Total: 256/149 | Lung resection  | Mechanical | Total: 183/322 | NA | NA | NA | NA | NA | 93.5(64.0-123.75) months |
| Aprile 2023 (108) | Italy | Retrospective Study | 177(138/39) | 6.29% | Total: 24 (13-40) | NA | NA | NA | NA | Stapler apicectomy, cold coagulation | Mechanical: Laser | Total: 94/83 | NA | NA | Total: 40(15-120)  | Total: 4(2-23) | NA | 83(24.0-144.0) months |
| Shigenobu 2023 (43) | Japan | Case-control Study | 207(185/22) | 13.00% | NA | NA | NA | NA | RG: 4/23NRG: 46/134 | Bullectomy | Mechanical: autologous blood and Absorbable cellulose mesh (PGA) | RG: 17/10NRG: 104/76 | RG: 17/10NRG: 157/23 | RG: 4/23NRG: 46/134 | NA | NA | Total: 31.3(1.0-143.2) months | 14.2 (0.7-104.2) months |

Data are presented as numbers, the mean±standard deviation, or median (range).

BMI, body mass index, CT, computed tomography; L/R, left/right; M/F, male/female; NA, not available; NOS, Newcastle–Ottawa scale; NRG, non-recurrence group; ORR, overall recurrence rate; PSP, primary spontaneous pneumothorax; RG, recurrence group.

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**Figure 1** Funnel plot for the risk factors of sex.