Supplementary Materials

Pulmonary Function Test Measurement Changes Over Time

Of the 47 studies included in the meta-analysis of imaging abnormalities, 26 also assessed PFTs and reported values as a percentage of predicted norms (**Table S1**). **Table S3** presents a summary of the results obtained from the REML, including overall means, and standard deviations of PFTs.

FEV_1/FVC (%), was reported in 17 studies, eight of which occurred at early-follow-up. The raw means (95% CI) were 85·4 (79·2-91·6) for all timepoints, 85·4 (78·8-92·0) for early follow-up, and 86·5 (80·8-92·2) for late follow-up. Interstudy heterogeneity was highest between early follow-up studies (I^2 = 99·34%), followed by all timepoints (I^2 = 99·20%), and then late follow-up (I^2 = 99·03%). No heterogeneity was associated with follow-up time, and the relationship between FEV_1/FVC, and follow-up time was not significant (p = 0·80).

23 studies evaluated FEV_1 percent predicted (%pred), and the raw mean for all of these was 91·4 (88·2-94·6). The raw mean FEV_1 %pred for the 12 studies with an early follow-up time was 91·4 (87·5-95·3), and 96·2 (94·2-98·3) for the 11 studies with a late follow-up time. The I^2 values were 90.75%, 93·82%, and 75·55%, respectively. The R^2 was 18·40%, and follow-up time was significantly associated with increased FEV_1 (p = 0·03).

24 studies reported FVC %pred. 11 of these had an early follow-up. The raw mean FVC %pred for all timepoints, early follow-up, and late follow-up were 92·5 (88·0-97·0), 92·5 (87·5-97·5), and 96·1 (92·5-100·0), respectively. Interstudy heterogeneity for all timepoints was 94·73%, 95·17% in early follow-up and 93·89% in late follow-up. Heterogeneity due to follow-up was 0·53% and the relationship between follow-up time was not significant (p = 0·24).

24 studies reported DLCO %pred, 12 at early follow-up. The raw mean of all timepoints for DLCO %pred was 76·1 (71·1-81·2). At the early timepoint, the mean was 76·1 (70·8-81·5), and

it was 84·7 (80·0-89·5) at late timepoint. Interstudy heterogeneity for each timepoint was 95·30%, 96·02%, and 94·28%, respectively. 17·57% of heterogeneity was accounted for by follow-up time. Follow-up time significantly impacted DLCO (p = 0·02).

A meta-regression was performed between dyspnea and FEV1 (% predicted), and dyspnea and DLCO (% predicted). Neither were significantly correlated (p = 0·39, 0·16, respectively). The regression included the nine studies reporting both FEV1 and dyspnea had an R^2 of 0·00%, and an I^2 of 76·35%. The regression including DLCO also included nine studies and had slightly more interstudy heterogeneity (I^2 = 88·35%) and 7·39% of heterogeneity in DLCO was attributable to dyspnea proportions within the cohort. Furthermore, DLCO was not significantly associated with any given imaging abnormality. However, while the meta-analysis of all PFTs did not exhibit significant publication bias, the meta-regression between DLCO and CT abnormalities did have an Egger's test p value < 0.05.

After stepwise removal of studies which contributed to heterogeneity, our findings remain mostly the same. DLCO and FEV1 significantly changed over time between early and late follow-up time points, but remained in the normal range, while FEV1/FVC and FVC did not. Furthermore, the relationship between FEV1 and dyspnea, and DLCO and dyspnea also remained non-significant. However, the relationship between DLCO and imaging abnormalities became significant after the removal of these studies. Notably, GGOs and DLCO, and reticulations and DLCO were negatively correlated (i.e., higher average DLCO (% pred) was associated with a lower proportion of these abnormalities). The R^2 for these meta regressions were 92.09%, and 97.49%, respectively (p < 0.0001, p<0.0001).

Stepwise Removal of Studies in the proportion of Imaging Abnormalities and associated meta-regressions

Results from the stepwise removal of heterogeneity are available in Table S4. Briefly, most of our findings are consistent with what was obtained prior to the removal of these studies.

However, many of the effects became much more pronounced. Notably, all specific abnormalities (GGOs, reticulations, bronchiectasis, consolidations, and fibrosis) significantly changed over time ($p < 0.001$ for all). Interestingly, while most of these abnormalities decreased, fibrosis and bronchiectasis increased over time.

Likewise, the meta-regression relationships also became stronger. Dyspnea was significantly correlated with all abnormalities, CT-only, and GGOs ($p < 0.0001$ for all). Age was significantly correlated with all abnormalities, CT-only, GGOs, reticulations, consolidations, bronchiectasis, and fibrosis ($p < 0.0001$ for all). Female sex was negatively correlated with all abnormalities, CT-only, GGOs, reticulations, consolidations, bronchiectasis, and fibrosis ($p < 0.0001$ for all). R^2 values for these relationships exceeded 90%. Results are described in further detail in Table S5.

Table S1. Summary of Studies Included in the Meta-Analysis

Authors	Country	Study Period (mm/yy)	Sample Size	Age, mean ± SD or median [IQR] years	Acute COVID-19 Severity	Time from acute illness (months)	Imaging Technology	Outcomes used for meta-analysis
Balbi et. al.(23)	Italy	02/20 - 05/20	91	66 [59-71]	Hospitalized	3	CT	Total Patients with Any Imaging Abnormality, GGO, Reticulations, Consolidations, Dyspnea, PFTs
Bardakci et. al.(24)	Turkey	03/20 - 07/20	60	N/A	Hospitalized	6	CT	Total Patients with Any Imaging Abnormality
Cao et. al.(26)	China	01/20 - 03/20	51	43·5 ± 15·9	Hospitalized, mixed severity	3	CT	Total Patients with Any Imaging Abnormality, GGO, Dyspnea
Caruso et. al.(27)	Italy	03/20 - 05/20	118	65 ± 12	Hospitalized with moderate to severe COVID-19 pneumonia	6	CT	Total Patients with Any Imaging Abnormality, GGO, Reticulations, Consolidations, Fibrosis, Bronchiectasis, Dyspnea
Chen et. al.(28)	China	02/20 - 03/20	41	51 [38-59]	Hospitalized, mixed severity	3, 6, 12	CT	Total Patients with Any Imaging Abnormality, PFTs
Dai et. al.(29)	China	01/20 - 10/20	45	48 ± 14	Hospitalized, mixed severity	6	CT	Total Patients with Any Imaging Abnormality, GGO, Reticulations, Consolidations

Fortini et. al.(30)	Italy	03/20 - 05/20	59	68·2 ± 12·8	Hospitalized, not severe	3	Ultrasound	Total Patients with Any Imaging Abnormality, Dyspnea, PFTs
Frija-Masson et. al.(31)	France	02/20 - 08/20	137	59 [50-68]	Hospitalized	3	CT	GGO, Reticulations, Fibrosis', PFTs
Froidure et. al.(32)	Belgium	03/20 - 06/20	107	60 [53–68]	Hospitalized, mixed severity	3	CT	GGO, Reticulations, Consolidations, Fibrosis, Dyspnea, PFTs
Gamberini et. al.(33)	Italy	02/20 - 05/20	37	64 [55-70]	ICU	9 to 12	CT	GGO, Reticulations, Consolidations, Fibrosis. Bronchiectasis, PFTs
Gianella et. al.(34)	Switzerland	03/20 - 04/20	39	62·5 [51-71]	Hospitalized, mixed severity	3	CT	Total Patients with Any Imaging Abnormality, GGO, PFTs
Gonzalez et. al.(35)	Spain	03/20 - 06/20	57	60 [48-65]	ICU, experienced ARDS	3	CT	Total Patients with Any Imaging Abnormality, GGO, Reticulations, Consolidations, Fibrosis, Bronchiectasis, Dyspnea, PFTs
Grist et. al.(36)	The United Kingdom	08/20 - 12/20	9	57 ± 7	Hospital, excluding invasive ventilation	5	Xenon Magnetic Resonance Imaging, CT	Total Patients with Any Imaging Abnormality, Dyspnea, PFTs
Guler et. al.(37)	Switzerland	05/20 - 09/20	52	Mild-52·9 ± 10·9 Severe-	Mixed	4	CT	Reticulations, Consolidations, Bronchiectasis

				Critical: 60·3 ± 12·0				
Gurbani et. al. (71)	Spain	03/20-08/20	77	57±13.14	Hospitalized	4	Ultrasound	Total Patients with Any Imaging Abnormality, PFTs, Dyspnea
Hellemons et. al.(38)	The Netherlands	02/20 - 07/20	87	58·2 ± 12·3	Hospitalized, ICU	3, 6	CT	Total Patients with Any Imaging Abnormality, GGO, Reticulations, Consolidations, Fibrosis, Bronchiectasis, PFTs
Holdsworth et. al. (70)	UK	08/20-04/21	171	39 [30-46.7] range 17-61	Severe acute COVID illness (hospital admission)	3	CT	Total Patients with Any Imaging Abnormality, GGO, Fibrosis, PFTs, Dyspnea
Hu et. al.(39)	China	01/20 - 24/20	18	Moderate: 43·76 ± 12·89 Severe: 52·44 ± 11·88	Hospitalized, no mechanical ventilation	5	CT	Total Patients with Any Imaging Abnormality, GGO
Huang et. al.(40)	China	01/20 - 05/20	353	57 [47-65]	Hospitalized	6	CT	Total Patients with Any Imaging Abnormality, GGO, Reticulations, Consolidations
Johnsen et. al.(41)	Denmark	03/20 - 08/20	57	51 ± 13	Mixed, hospitalized, and non-hospitalized	3	CT	Total Patients with Any Imaging Abnormality, PFTs
Jutant et. al. (68)	France	06/20-10/20	171	57.3±13.2	ICU and non-ICU hospitalized	4	CT	Total Patients with Any Imaging Abnormality, GGOs, Reticulations,

Labarca et. al.(42)	Chile	04/20 - 07/20	60	Mild: 39·2 ± 14·3 Moderate: 47·4 ± 11 Severe: 50·0 ± 10·3	Hospitalized from mild to severe	4	CT	Fibrosis, Consolidations, PFTs, Dyspnea Total Patients with Any Imaging Abnormality, GGO, Reticulations, Consolidations, Fibrosis, Bronchiectasis
Lerum et. al.(43)	Norway	Mar-20	15	ICU: 52 [50-59]	Hospitalized, ICU (note: only ICU cohort met inclusion criteria)	3	CT	GGO, PFTs
Li et. al.(44)	China	01/20 - 04/20	86	Pulmonary Fibrosis: 33·06 ± 17·50 No pulmonary Fibrosis: 50·68 ± 13·25	Hospitalized, mixed	3, 4	CT	GGO, Bronchiectasis
Liao et. al.(45)	China	03/21 - 04/21	256	39·0 [33·0–48·0]	Hospitalized	12	CT	Total Patients with Any Imaging Abnormality, GGO, Reticulations, Consolidations, Fibrosis, Bronchiectasis, PFTs
Liu et. al.(46)	China	02/20 - 03/20	41	50 ± 14	Hospitalized	3, 7	CT	GGO, Reticulations, Consolidations, Bronchiectasis

Luger et. al.(47)	Austria	04/20 - 08/20	86	57 [51-70]	Hospitalized, mixed severity	3, 6, 12	CT	Total Patients with Any Imaging Abnormality, GGO, Reticulations, Consolidations
Martino et. al. (67)	Italy	03/20-05/20	52 (6 mo) 47 (12 mo)	68 [56.5-75]	Hospitalized	6, 12	CT	GGOs, Consolidations, Bronchiectasis, Reticulations, PFTs, Dyspnea
McGroder et. al.(48)	The Unites States of America	03/20 - 05/20	76	54 ± 13·7	Hospitalized	4	CT	Total Patients with Any Imaging Abnormality, GGO, Reticulations, Bronchiectasis, PFTs
Miwa et. al.(49)	Japan	04/20 - 12/20	17	63 [59-67]	Hospitalized, invasive mechanical ventilation	3	CT	Total Patients with Any Imaging Abnormality, GGO, Consolidations, PFTs
Mohr et. al.(50)	Germany	04/20 - 09/20	10	50 ± 13·1	Hospitalized, some with mechanical ventilation	4	CT	Total Patients with Any Imaging Abnormality, GGO
Muhammad et. al. (69)	Pakistan	03/21-03/22	173	53.62	Hospitalized	3, 6	CT	Fibrosis
Mumoli et. al.(51)	Italy	05/20 - 08/20	77	62·7 ± 9·5	Hospitalized, mixed severity	3	CT and x-ray	Total Patients with Any Imaging Abnormality, GGO, Fibrosis, Dyspnea
Nabahati et. al.(52)	Iran	Mar-20	173	53·62 ± 13·67	Hospitalized. Moderate or severe pneumonia	3, 6	CT	Fibrosis, Bronchiectasis

Noel-Savina et. al.(53)	France	04/20 - 09/20	72	60·5 ± 12·8	Hospitalized, ICU and non-ICU, COVID-19 pneumonia	4	Scintigraphy and CT	Total Patients with Any Imaging Abnormality, GGO, Reticulations, Bronchiectasis, Dyspnea, PFTs
Núñez-Fernández et. al.(54)	Spain	03/20 - 05/20	200	62 [50-71]	Hospitalized, mixed severity	3	X-ray	Total Patients with Any Imaging Abnormality, PFTs
Remy-Jardin et. al.(55)	France	03/20 - 04/20	55	59·7 ± 13·7	Hospitalized	3	Dual Energy CT Angiography	Total Patients with Any Imaging Abnormality, GGO, PFTs
Robey et. al.(56)	The United Kingdom	03/20 - 06/20	72	58	Hospitalized, ICU and non-ICU	4	CT	Total Patients with Any Imaging Abnormality, GGO, Fibrosis
Skala et. al.(57)	Czech Republic	06/2020 - 10/2020	102	46·7	Hospitalized and non-hospitalized	3	CT	Total Patients with Any Imaging Abnormality, GGO, Consolidations, Fibrosis, Bronchiectasis, Dyspnea
Truffaut et. al.(59)	Belgium	03/20 - 06/20	22	54·6 ± 10·9	Hospitalized, ARDS	3	CT	Total Patients with Any Imaging Abnormality, GGO, Consolidations, Fibrosis, PFTs
van Gassel et. al.(60)	The Netherlands	03/20 - 05/20	46	63·00 [55·00-68·00]	Hospitalized, ICU	3	CT	Total Patients with Any Imaging Abnormality, GGO, Reticulations, Fibrosis, PFTs
Vijayakumar et. al.(61)	The United Kingdom	03/20 - 06/20	73	59 ± 13	Hospitalized	3, 12	CT	Total Patients with Any Imaging Abnormality, GGO, Reticulations, Consolidations,

								Fibrosis, Bronchiectasis, Dyspnea
Wu Q et. al.(62)	China	01/20 - 09/20	48	47 [36·8-57·3]	Hospitalized	6	CT	Total Patients with Any Imaging Abnormality, GGO, Reticulations, Bronchiectasis, Dyspnea
Wu X et. al.(63)	China	N/A	83	60 [52–66]	Hospitalized with mixed severity not requiring mech ventilation	3, 6, 9, 12	CT	Total Patients with Any Imaging Abnormality, GGO, Reticulations, Bronchiectasis, Dyspnea, PFTs
Zhang et. al.(65)	China	01/20 - 03/20	40	57 [40-68]	Hospitalized	8	CT	Total Patients with Any Imaging Abnormality, GGO, Reticulations, Consolidations
Zhao et. al.(8)	China	01/21 - 02/21	94	48 ± 11·90	Hospitalized	12	CT	Total Patients with Any Imaging Abnormality, GGO, Reticulations, Consolidations, Fibrosis, PFTs
Zhou et. al.(66)	China	03/20 - 03/20	164	Severe/Critical : 63·00 [56·00-69·00] Mild/Moderate: 56·00 [47·50-63·00] Asymptomatic:	Hospitalized and non-Hospitalized	4	CT	Total Patients with Any Imaging Abnormality, GGO, Reticulations, Fibrosis, Bronchiectasis

	46·00 [39·50-57·00]

Abbreviations: CT, computed tomography; GGOs, ground glass opacities; ICU, intensive care unit; PFTs, pulmonary function testing

Table S2. Summary of Meta-Regression between Imaging Abnormalities and Dyspnea Proportions, Sex, and Age

Abbreviations: CT, computed tomography; GGOs, ground glass opacities; NA, not available due to lack of studies. [a] Correlations for female are negative.

Evaluated Factors	Any Abnormality		Any Abnormality (CT only)		GGOs		Reticulations		Bronchiectasis		Consolidations		Fibrosis	
	R^2	p-value	R^2	p-value	R^2	p-value	R^2	p-value	R^2	p-value	R^2	p-value	R^2	p-value
Cohort Proportion of Dyspnea	28 %	0·012	14 %	0·10	0·0 %	0·47	NA		NA		NA		NA	
Cohort Proportion of Females [a]	3·8 %	0.11	6·3 %	0.069	0·0 %	0.36	32 %	0·001	37 %	0·001	18 %	0·025	0·0 %	0·70
Cohort Mean Age	24 %	0·002	30 %	0·001	21 %	0·004	38 %	0.001	14 %	0·081	0·0%	0·55	15 %	0·051

Table S3. Summary of Meta-Regression of Pulmonary Function Testing

Pulmonary Function	Patients Evaluated at Each Time Point, N	Raw Mean, All Timepoints (95% CI)	Raw Mean Early Follow-up (95% CI)	Raw Mean F/U**, (95% CI)	Change from early to late follow-up, p-value†	Heterogeneity attributable to follow-up time‡
FEV1/FVC (percent)	1532 (total), 700 (early F/U), 832 (late F/U)	85·4 (79·2-91·6)	85·4 (78·8-92·0)	86·5 (80·8-92·2)	0·80	0·00 %
FEV1 (percent predicted)	2019 (total), 1049 (early F/U), 970 (late F/U)	91·4 (88·2-94·6)	91·4 (87·5-95·3)	96·2 (94·2-98·3)	0·024	14 %
FVC (percent predicted)	2035 (total), 919 (early F/U), 1116 (late F/U)	92·5 (88·0-97·0)	92·5 (87·5-97·5)	96·1 (92·5-100·0)	0·24	0·53 %
DLCO (percent predicted)	2099 (total), 1025 (early F/U), 1075 (late F/U)	76·1 (71·1-81·2)	76·1 (70·8-81·5)	84·7 (80·0-89·5)	0·034	18 %

Abbreviations: FEV1, Forced Expiratory Volume in the first second; FVC, Forced Vital Capacity; DLCO, Diffusing Capacity for Carbon Monoxide; F/U, follow-up; CI, confidence interval. *3 months since acute infection. **>3 months since acute infection. †p-value from random effects model. ‡R^2 from random effects model.

Table S4. Total and specific chest imaging abnormalities during follow-up after stepwise removal of heterogeneity

Abnormality	Studies Included/Total studies	Overall prevalence of imaging abnormalities (95% CI)	At early F/U*, prevalence (95% CI)	At late F/U**, prevalence (95% CI)	Change from early to late follow-up, p-value†	Heterogeneity attributable to follow-up time‡
Any abnormality	20/38 (total), 7/18 (early F/U), 13/20 (late F/U)	65.8 [62.9-68.7]	62.5 [57.3-67.7]	57·4% (64·3-70·6%)	0.098	53 %
Any abnormality (CT imaging subgroup)	19/34 (total), 7/16 (early F/U), 12/18 (late F/U)	65·8% (62·6-69·0%)	62·5% (57·3-67·7%)	67·6% (63·9-71·3%)	0·12	28 %
GGOs	23/37 (total), 10/18 (early F/U, 13/19 (late F/U)	51·6% (46·6-56·7%)	62·6% (57·9-67·4%)	43·2% (40·4-46·1%)	>0.0001	93 %
Reticulations	11/22 (total), 3/7 (early F/U), 8/15 (late F/U)	14·2% (7·48-20·9%)	29·3% (23·9-34·7%)	7·83% (3·75-11·9%)	>0.0001	100 %
Bronchiectasis	9/19 (total), 4/7 (early F/U), 5/12 (late F/U)	19·6% (12·6-26·5%)	9·68% (4·99-14·4%)	27·3% (22·2-32·5%)	>0·0001	89 %
Consolidations	15/22 (total), 7/10 (early F/U), 8/12 (late F/U)	5·75% (3·03-8·47%)	9·34% (4·84-13·8%)	3·67% (0·02-7·09%)	0·049	0·0 %
Fibrosis	8/21 (total), 4/11 (early F/U), 4/10 (late F/U)	13·1% (7·41-18·7%)	6·60% (1·77-11·44%)	19·8% (14·5-25·0%)	0·0003	100 %

Abbreviations: CT, computed tomography; GGOs, ground glass opacities; F/U, follow-up; CI, confidence interval. *3 months since acute infection. **>3 months since acute infection. †p-value from random effects model. ‡R2 from random effects model.

Table S5. Summary of Meta-Regression between Imaging Abnormalities and Dyspnea Proportions, Sex, and Age after stepwise removal of heterogeneity

Evaluated Factors	Any Abnormality		Any Abnormality (CT only)		GGOs		Reticulations		Bronchiectasis		Consolidations		Fibrosis	
	R^2	p-value	R^2	p-value	R^2	p-value	R^2	p-value	R^2	p-value	R^2	p-value	R^2	p-value
Cohort Proportion of Dyspnea	97 %	<0.0001	95 %	<0.0001	100 %	<0.0001	NA		NA		NA		NA	
Cohort Proportion of Females [a]	95 %	<0.0001	92 %	<0.0001	92 %	<0.0001	89 %	<0·0001	78 %	0·0001	96 %	<0·0001	97 %	<0·0001
Cohort Mean Age	98 %	<0.0001	100 %	<0·0001	93 %	<0.0001	97 %	<0.0001	87 %	<0·0001	87 %	<0·0001	78 %	<0·0001

Abbreviations: CT, computed tomography; GGOs, ground glass opacities; NA, not available due to lack of studies. [a] Correlations for female are negative.

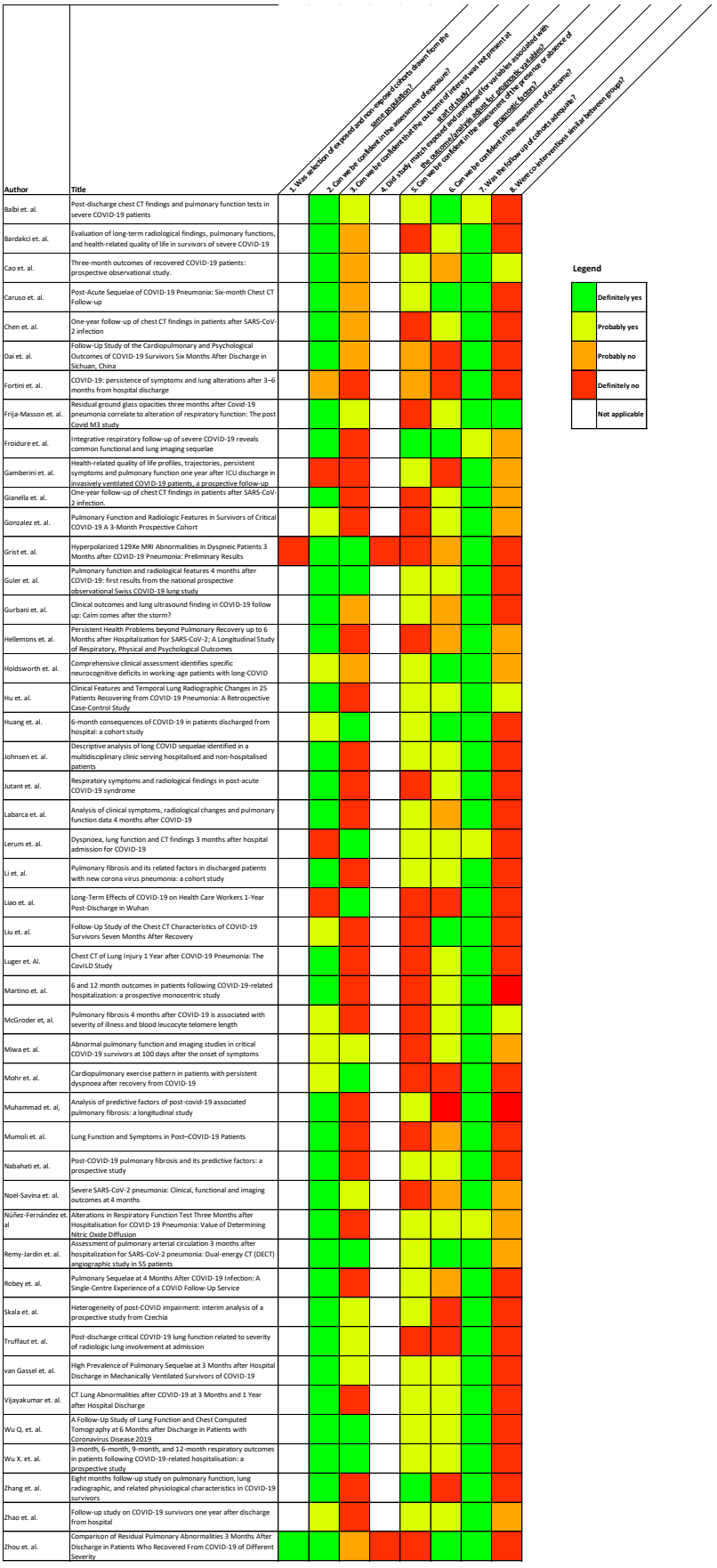

Figure S1 Clarity Bias Assessment

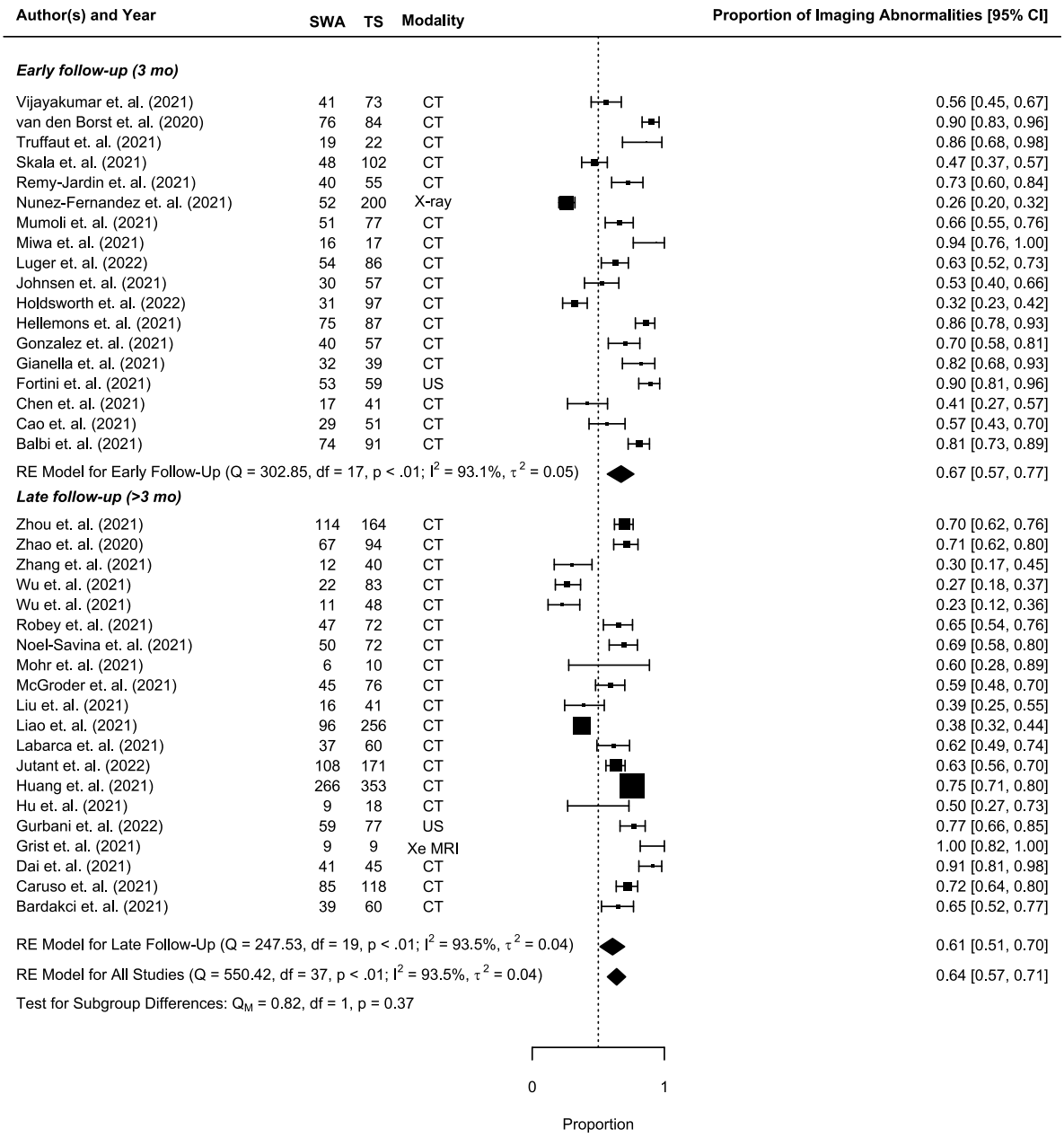

Figure S2: Forest Plot Proportion of Any Imaging Abnormality at Any, Early, and Late Follow-up.

Abbreviations: SWA, subjects with abnormality; TS, total subjects; RE, random effects

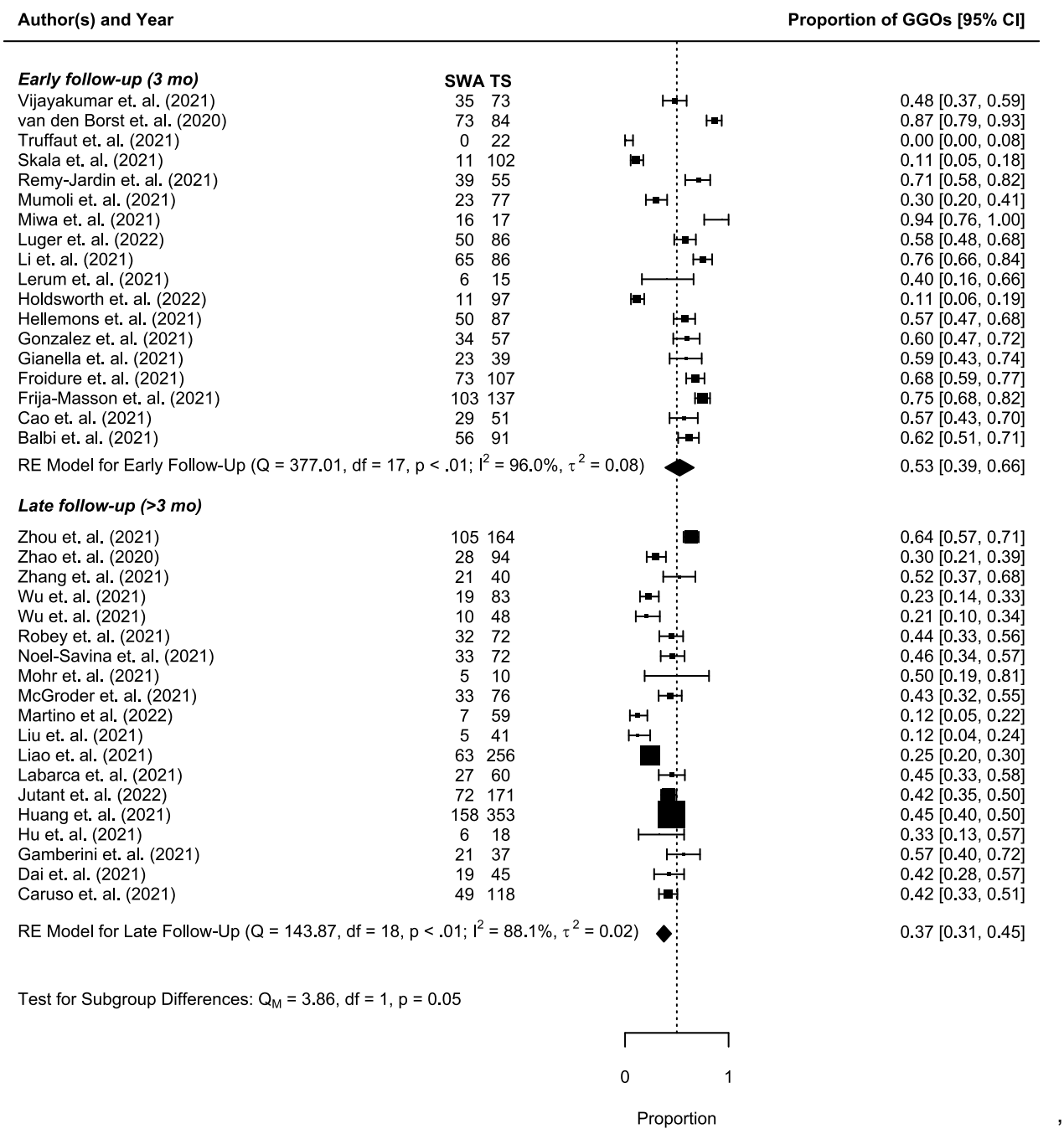

Figure S3: Forest Plot Proportion of GGOs at Any, Early, and Late Follow-up. Abbreviations: SWA, subjects with abnormality; TS, total subjects; RE, random effects

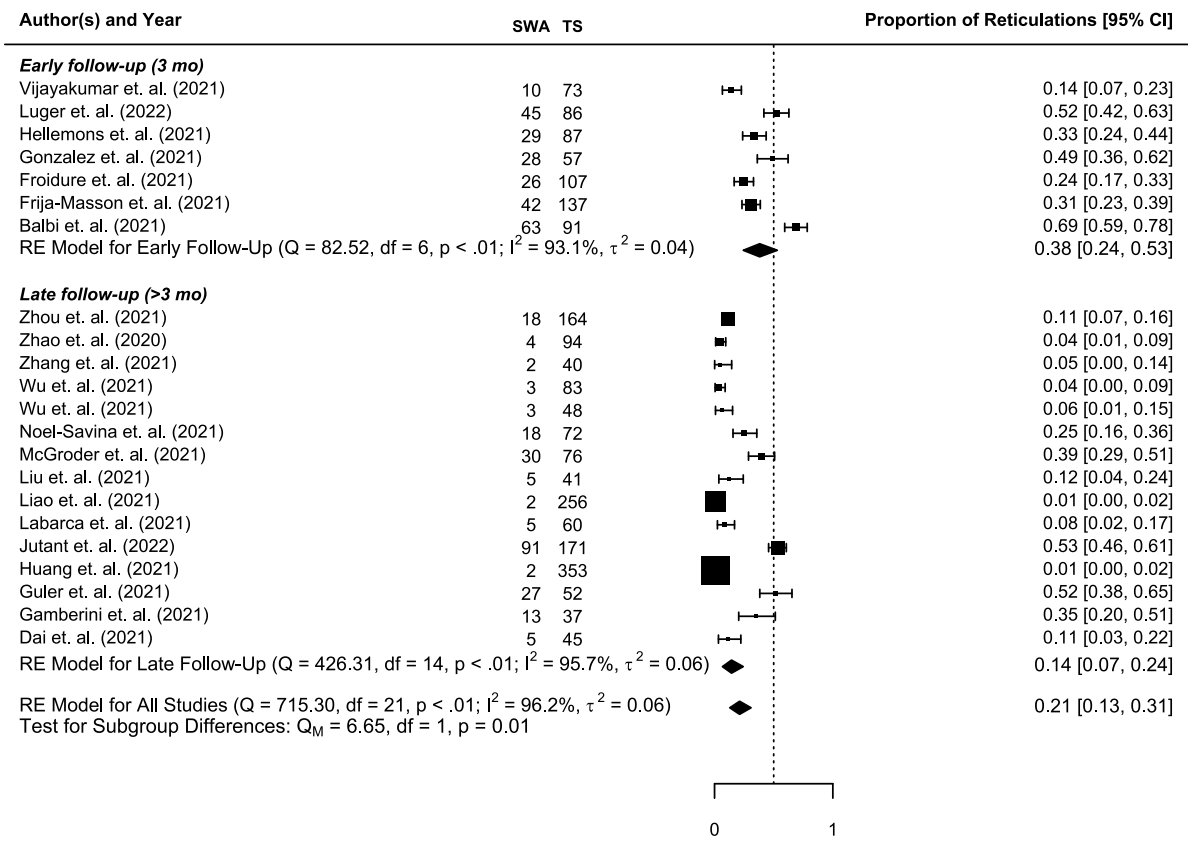

Figure S4: Forest Plot Proportion of Reticulations at Any, Early, and Late Follow-up. Abbreviations: SWA, subjects with abnormality; TS, total subjects; RE, random effects

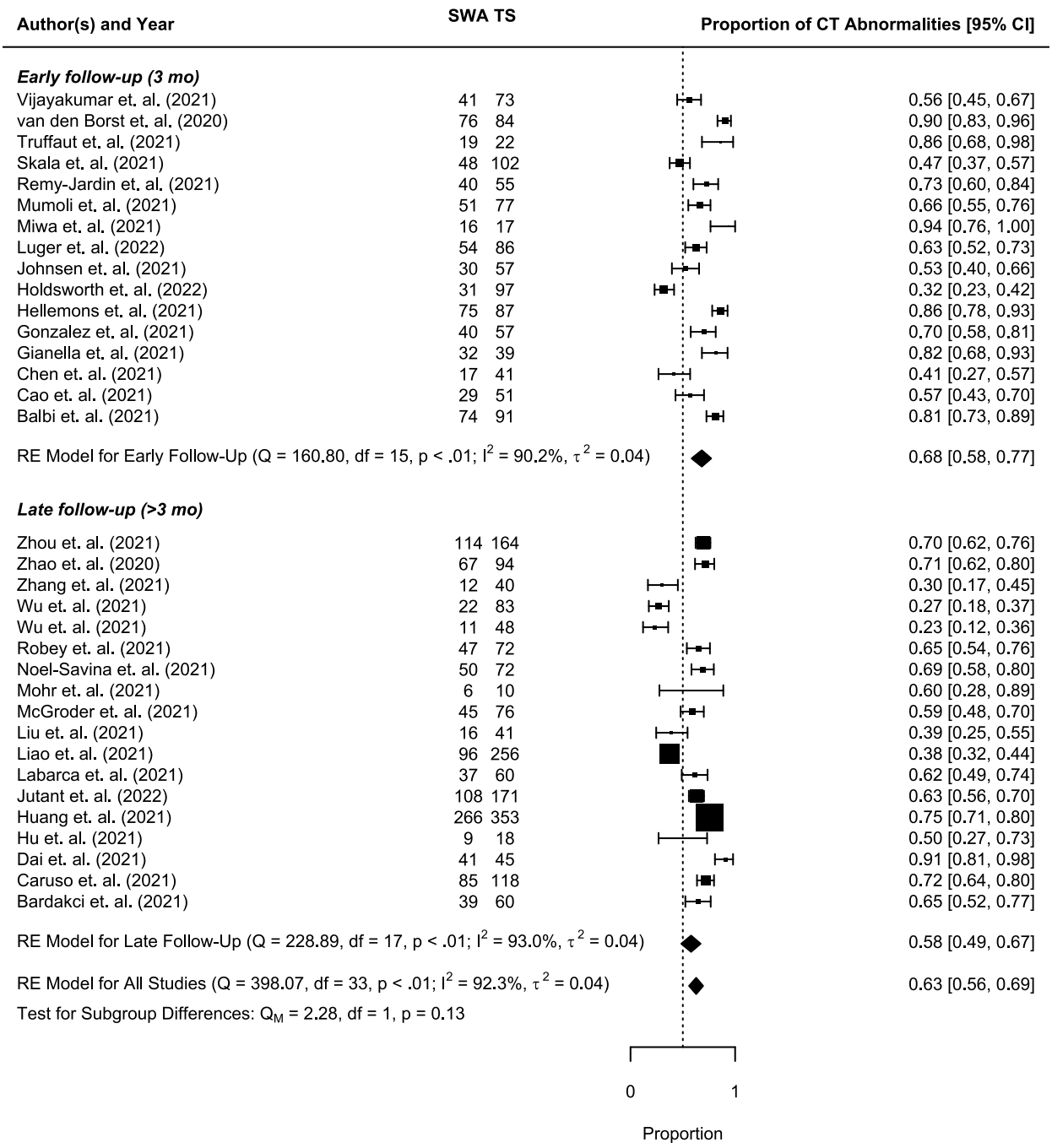

Figure S5 Forest Plot Proportion of CT-only Abnormalities at Any, Early, and Late Follow-up

Abbreviations: SWA, subjects with abnormality; TS, total subjects; RE, random effects

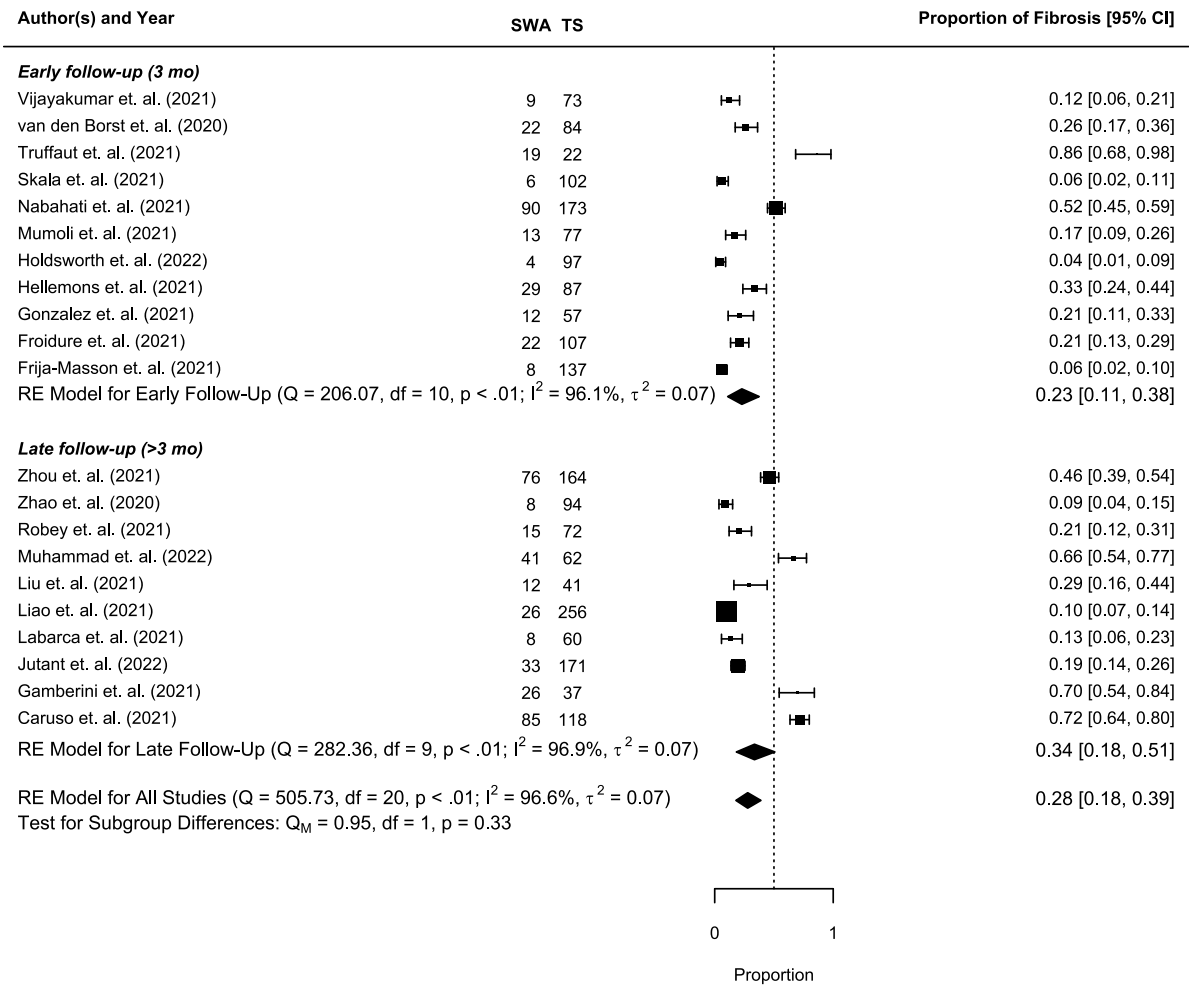

Figure S6 Forest Plot Proportion of Fibrosis at Any, Early, and Late Follow-up

Abbreviations: SWA, subjects with abnormality; TS, total subjects; RE, random effects

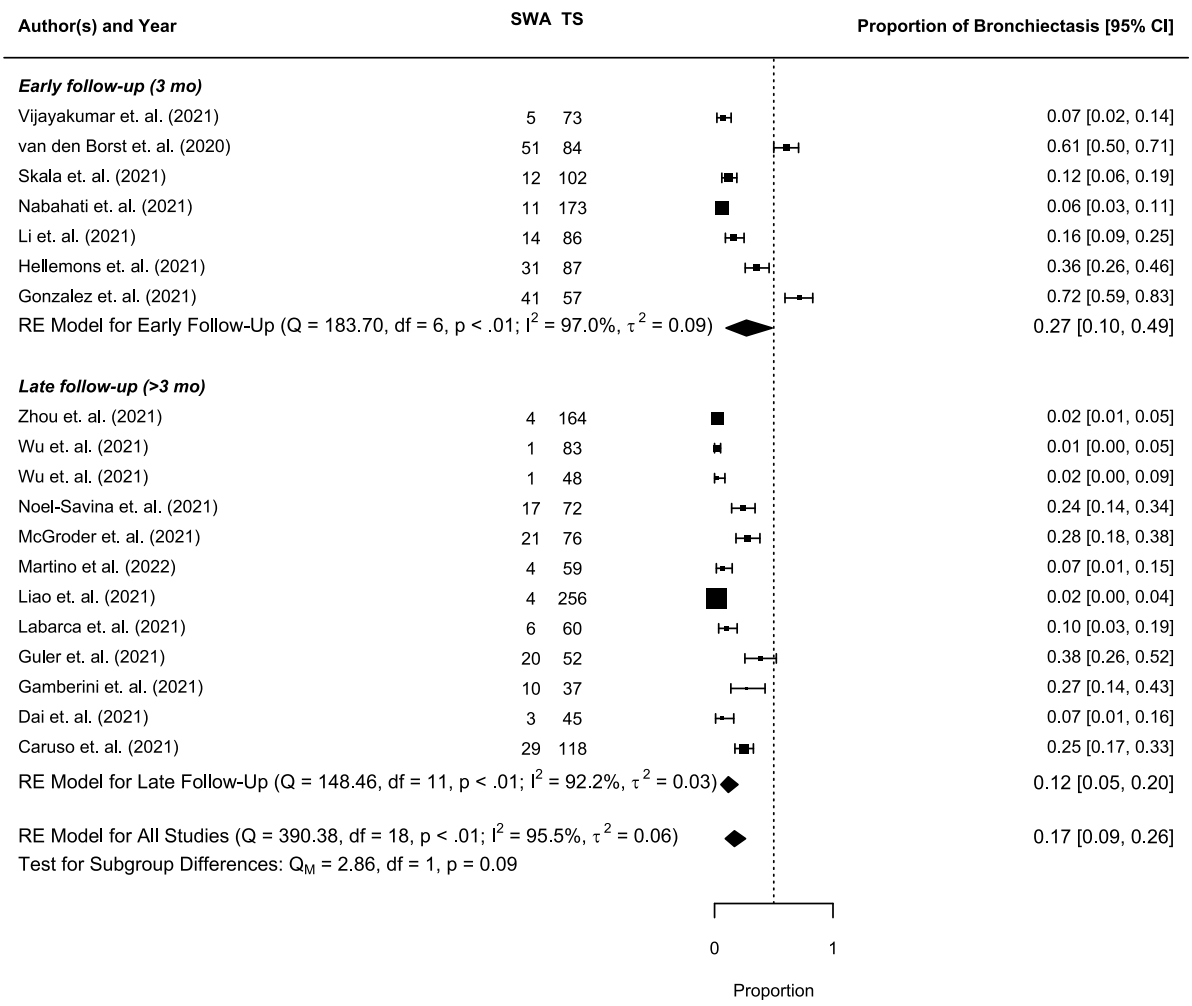

Figure S7 Forest Plot Proportion of Bronchiectasis at Any, Early, and Late Follow-up Abbreviations: SWA, subjects with abnormality; TS, total subjects; RE, random effects

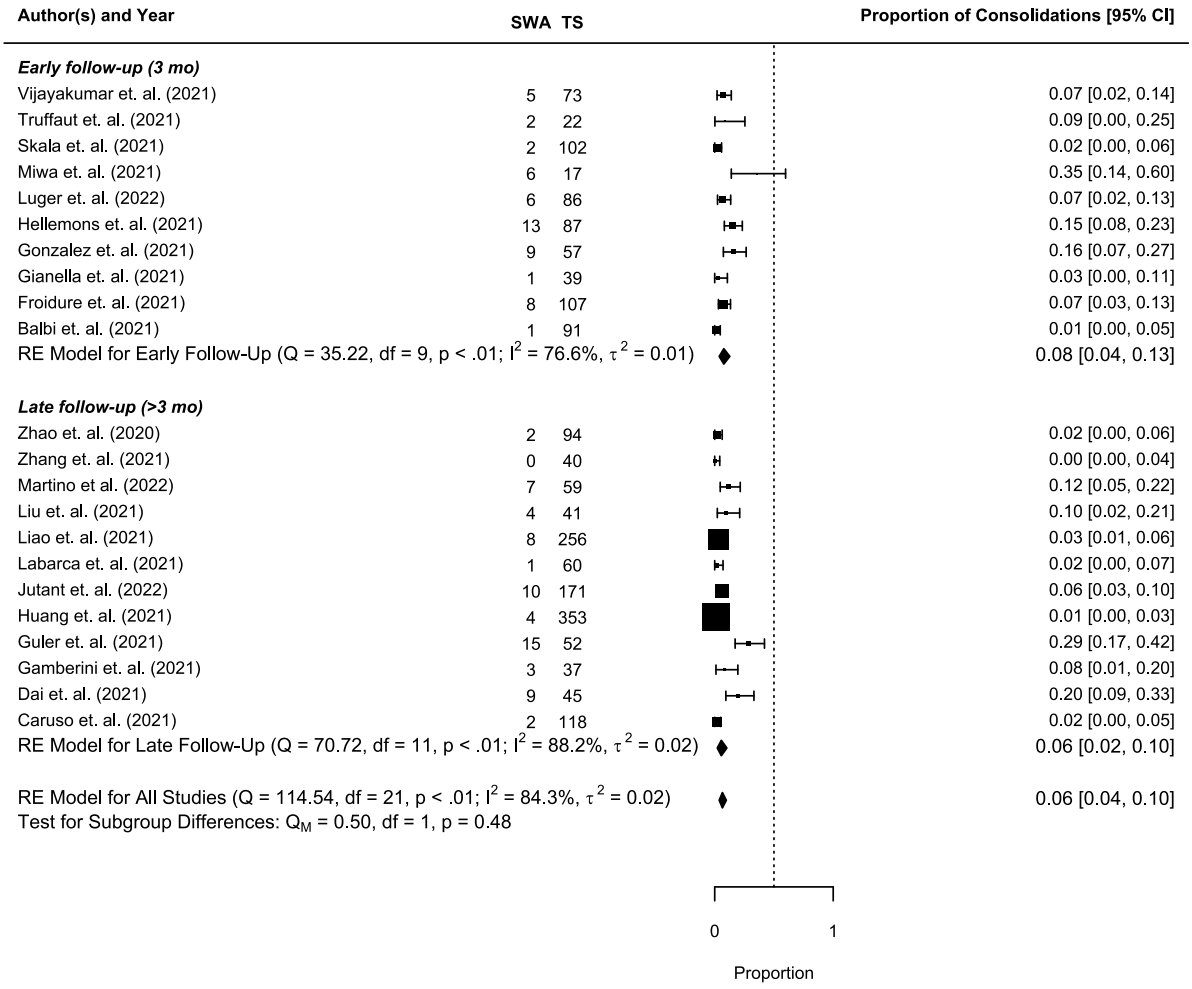

Figure S8 Forest Plot Proportion of Consolidations at Any, Early, and Late Follow-up Abbreviations: SWA, subjects with abnormality; TS, total subjects; RE, random effects

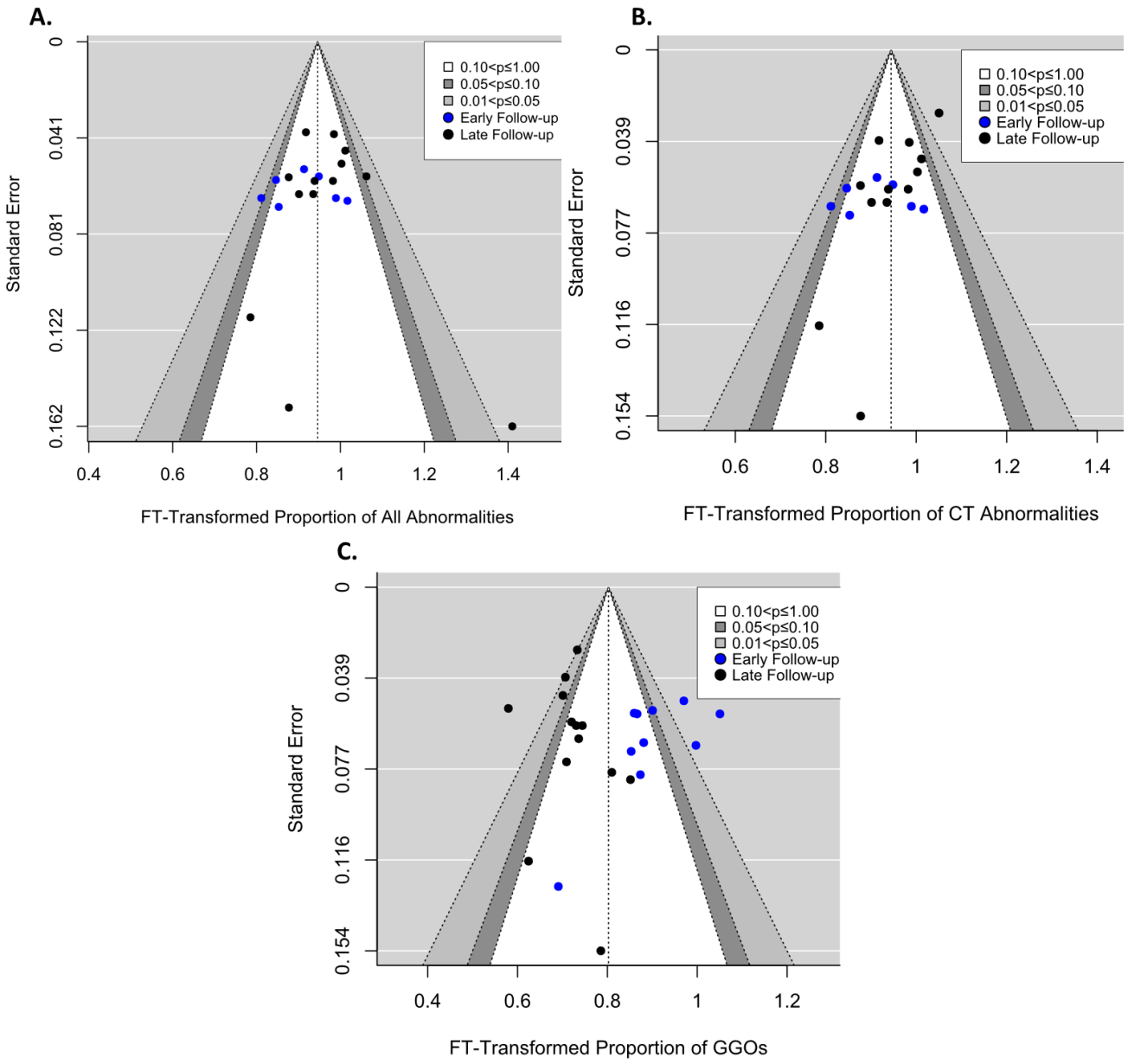

Figure S9. Funnel plots assessing publication bias of A) All Abnormalities across all modalities, B) CT-only abnormalities, and C) GGOs