# Supplementary material

Systematic review and critical appraisal of prediction models for diagnosis and prognosis of COVID-19 infection

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### Supplementary material: search strings

Search string bioRxiv, medRxiv, arXiv: ncov or corona or wuhan or COVID Search string PubMed: ("Wuhan coronavirus" [Supplementary Concept] OR "COVID-19" OR "2019 ncov"[tiab] OR (("novel coronavirus"[tiab] OR "new coronavirus"[tiab]) AND (wuhan[tiab] OR 2019[tiab])) OR 2019-nCoV[All Fields] OR (wuhan[tiab] AND coronavirus[tiab])))))

Search string EMBASE: ncov OR (wuhan AND corona) OR COVID

#### Supplementary material: data extraction

Data were extracted on the following items:

- Population (China, other).
- Intended timing of model use (screening of patients, ICU admission, etc.).
- Setting (inpatients, outpatients, suspected cases).

• Participants: study design, recruitment method, number of centres, inclusion criteria, exclusion criteria, patient age (mean and standard deviation or median and interquartile range), patient sex (n males and percentage).

• Predictors: list of candidate predictors, number of candidate predictors, number of additional degrees of freedom for candidate predictors (e.g. for categorical variables with more than two categories or for modelling continuous variables non-linearly), predictors in the final model, number of predictors in the final model, number of additional degrees of freedom in the final model.

• Outcome: definition of outcome, timing of outcome.

• Analysis:

- Total number of participants, total number of participants with the outcome.
- o Total number of participants with any missing predictor or outcome values.
- Method for handling missing data.
- Method for prediction model development (logistic regression, Cox regression, neural network, tree-based, etc.).
- Method for selection of predictors during multivariable analysis and the criteria used (e.g., p-value used for selection).

- Handling of categorical and continuous variables.
- Method(s) for validation (e.g. apparent, internal or external) and for optimism adjustment.
- Performance measures (calibration, discrimination, other) resulting from validation.
- Model presentation (coefficients and confidence intervals, final model, alternative presentation formats of the model such as a web-based tool).

• Standard signalling questions and items to assess risk of bias according to PROBAST (Moons, Wolff, et al.), on four domains:

- o participants
- $\circ$  predictors
- o outcome
- $\circ$  analysis

If risk of bias was high in at least one of the subdomains, overall risk of bias was judged to be high, as per PROBAST guidance (Moons, Wolff, et al.).

## Supplementary Table 1. Overview of the primary datasets used in included studies.

Authors	Description of dataset	Study design	Age mean ± se, median (IQR), or range	Sex (% male)
Hospital admission in general population			Tunge	
DeCaprio, Gartner, et al.	Medicare claims data 2015 to 2016	Administrative records	≥18	Unclear
Diagnosis				
Feng, Huang, et al.	First medical center, Chinese People's Liberation Army General Hospital, January 14 to February 9 (development) and February 10 to February 26 (validation)	Retrospective cohort	34 (IQR 29 to 42)	56%
Lopez-Rincon, et al.	International repository of genome sequences from the China National Center for Bioinformation (bigd.big.ac.cn/ncov), using all available samples on March 15	Unclear	Unclear	Unclear
Meng, Wang, et al.	Various regional medical institutions in China, between December 20 to February 10	Nonnested case-control	Dev: control: 68.5 (IQR 77 to 81), case: 46 (55 to 73); val: control: 66 (IQR 76 to 84), case: 48 (58 to 67)	Dev.: control: 73%, case: 69%; val.: control: 69%, case: 69%
Song, Xu, et al.	Zhijiang District of the First Affiliated Hospital of Zhejiang University School of Medicine	Unclear	38 (IQR 30 to 55)	49%
Yu, Shao, et al.	Wuhan's Children's Hospital, February 1 to March 3	Retrospective cohort	0 to 15 (range)	61%
Diagnostic imaging				
Barstugan, Ozkaya, et al.	Italian open data repository from the Societa Italiana di Radiologia Medica e Interventistica (sirm.org)	Unclear	Unclear	Unclear
Chen, Wu, et al.*	Renmin Hospital of Wuhan University	Unclear	Cases: 52 (IQR 38 to 69) Controls: 48 (IQR 35 to 55)	Cases: 35% Controls: 56%
Gozes, Frid-Adar, et al.	COVID cases: Wenzhou hospital (China), controls: chainz.cn registry, El Camino Hospital, California, LIDC registry (7 USA hospitals)	Nonnested case-control	Unclear	Unclear
Jin, Chen, et al.	Wuhan Union Hospital, Western Campus of Wuhan Union Hospital, Jianghan Mobile Cabin Hospital Wuhan, January 11 to February 29 2020, LICD-IDRI registry from NCI, USA; ILD-HUG registry from University Hospitals of Geneva, Switzerland	Unclear	Unclear	Unclear
Jin, Wang, et al.	Beijing Tsinghua Changgung Hospital, Wuhan No.7 Hospital, Zhongnan Hospital of Wuhan University, Tianyou Hospital Affiliated to Wuhan University of Science & Technology, Wuhan's Leishenshan Hospital, February 07 to February 20	Unclear	Unclear	Unclear
Li, Qin, et al.	6 Chinese hospitals, August 16 2016 to February 17 2020 (COVID-19 cases: December 31 2019 to February 17 2020)	Unclear	49 ± 15	55%
Shan, Gao, et al.	Shanghai Public Health Clinical Center and other centers in Shanghai	Unclear	Unclear	High

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	Shi, Xia, et al.	Tongji Hospital of Huazhong University of Science and Technology, Shanghai Public Health Clinical Center of Fudan University, and China- Japan Union Hospital of Jilin University	Nonnested case-control	Cases: 49 $\pm$ 14 years Controls: 56 $\pm$ 14	Cases: 52% Controls: 46%
	Wang, Kang, et al.	Xi'an Jiaotong University First Affiliated Hospital, Nanchang University First Hospital and Xi'an No.8 Hospital of Xi'an Medical College	Unclear	Unclear	Unclear
	Xu, Jiang, et al.	First Affiliated Hospital of Zhejiang University, No. 6 People's Hospital of Wenzhou, No. 1 People's Hospital of Wenling, January 19 to February 14	Nonnested case control	Unclear	Unclear
	Ying, Zheng, et al.	Renmin Hospital of Wuhan University, Third Affiliated Hospital, Sun Yat-Sen Memorial Hospital	Unclear	Unclear	Unclear
	Zheng, Deng, et al.	Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, December13 to January 23	Retrospective cohort	Cases: $51 \pm 15$ , control: $31 \pm 10$	Cases: 44%, Controls: 38%
Progn	osis				
	Bai, Fang, et al.	Wuhan Pulmonary Hospital, January 3 to February 13	Retrospective cohort	53 ± 13	50%
	Caramelo, Ferreira, et al.	Simulated based on data from Wuhan, China, December 8 to February 11	Simulation	Unclear	41%
	Gong, Ou, et al:	Guangzhou Eigth People's Hospital, Zhongnan Hospital of Wuhan University, Third Affiliated Hospital of Sun Yat-sen University, January 20 to March 2	Retrospective cohort	49 (dev) 52 (Val 1) 41.5 (Val 2)	47% (dev) 44% (Val 1) 50% (Val 2)
	Lu, Hu, et al.	Wuhan Hankou Hospital, January 21 to February 5	Retrospective cohort	Unclear	44%
	Qi, Jiang, et al.	5 hospitals from Ankang, Lishui, Zhenjiang, Lanzhou, Linxia between January 23 to February 8; date of last follow-up February 20	Prospective cohort	38 (IQR 26 to 47)	55%
	Shi, Yu, et al.	Hangzhou, Zhejiang Province, study dates unspecified, follow-up until February 17	Retrospective cohort	46 ± 19	53%
	Xie, Hungerford, et al.	Tongji Hospital and Jinyintan Hospital, admitted between January and February	Retrospective cohort	Tongji: 65 (IQR 54 to 73) Jinyintan: 56 (IQR 47 to 68)	Tongji: 52% Jinyintan: 35%
	Yan, Zhang, et al.	Tongji Hospital Wuhan, January 10 to February 18	Retrospective cohort	59 ± 16	59%
	Yuan, Yin, et al.	Hubei Public Health Clinical Center; central Hospital of Wuhan, January 1 to January 25	Retrospective cohort	60 (IQR 47 to 69)	44%

\* The study also included a prospective validation cohort of 27 consecutive patients (11 with COVID-19 pneumonia)

# Supplementary Table 2. Overview of modelling techniques for diagnosis and prognosis of

## COVID-19 infection.

Study	Outcome	Predictors in final model	Modelling technique
Hospital admission in gene	ral population		
Decaprio, Gartner, et al.	Hospital admission for COVID-19 pneumonia (proxy events)*1	Age; sex; number of previous hospital admissions; 11 diagnostic features; interactions between age and diagnostic features	Logistic regression
Decaprio, Gartner, et al.	Hospital admission for COVID-19 pneumonia (proxy events)*1	Age and 500+ features related to diagnosis history	Tree-based (XGBoost)
Decaprio, Gartner, et al.	Hospital admission for COVID-19 pneumonia (proxy events)*1	500+ undisclosed features, including age, diagnostic history, social determinants of health, Charlson comorbidity index	Tree-based (XGBoost)
Diagnosis			
Feng, Huang, et al.	Suspected COVID- 19 pneumonia	Age, temperature, heart rate, diastolic blood pressure, systolic blood pressure, basophil count, platelet count, mean corpuscular hemoglobin content, eosinophil count, monocyte count, fever, shiver, shortness of breath, headache, fatigue, sore throat, fever classification, interleukin-6	Logistic regression (LASSO) (vs. Logistic regression (ridge), decision tree, Adaboost)
Lopez-Rincon, et al.	COVID-19 diagnosis	Specific sequences of base pairs	Neural net (deep convolutional neural network)
Meng, Wang, et al.	COVID-19 diagnosis	Age; activated partial thromboplastin time; red blood cell distribution width-CD; uric acid; triglyceride; serum potassium; albumin/globulin; 3- hydroxybutyrate; serum calcium	LASSO followed by logistic regression
Song, Xu, et al.	COVID-19 diagnosis	Fever; history of close contact; signs of pneumonia on CT; neutrofil-to-lymphocyte ratio; highest body temperature; sex; (age, meaningful respiratory syndromes)	Logistic regression
Yu, Shao, et al.	Severe disease (yes/no) defined based on clinical symtoms	Direct Bilirubin; Alaninetransaminase	Tree-based (decision tree)
Diagnostic imaging			
Barstugan, Ozkaya, et al	COVID-19 diagnosis	Not applicable	Support vector machine
Chen, Wu, et al.	COVID-19 pneumonia	Not applicable	Neural net (Unet ++)
Gozes, Frid-Adar, et al.	COVID-19 diagnosis	Not applicable	Neural net (deep convolutional neural network)
Jin, Chen, et al.	COVID-19 diagnosis	Not applicable	Neural net (various segmentation and classification models)
Jin, Wang, et al.	COVID-19 pneunomia	Not applicable	Neural net (convolutional neural network)
Li, Qin, et al.	COVID-19 diagnosis	Not applicable	Neural net (COVNet)
Shan, Gao, et al.	Segmentation and quantification of infection regions in lung from chest CT scans.	Not applicable	Neural net (VB-Net)

G1 ' X7' / 1	COVID 10		
Shi, Xia, et al.	COVID-19 pneunomia	5 categories of location features from imaging: volume, number, histogram, surface, radiomics	LASSO followed by tree- based (infection size-aware random forest (iSARF) method vs. logistic regression, support
			vector machine, Neural net.
Wang, Kang, et al.	COVID-19 diagnosis	Not applicable	Neural net (convolutional neural network)
Xu, Jiang, et al.	COVID-19 diagnosis	Not applicable	Neural net (convolutional neural network)
Ying, Zheng, et al.	diagnosis of COVID-19 vs healthy controls	Not applicable	Neural net (DRENet vs. VGG16, DenseNet, ResNet for comparison)
Ying, Zheng, et al.	diagnosis of COVID-19 vs bacterial pneumonia	Not applicable	Neural net (DRENet vs. VGG16, DenseNet, ResNet for comparison)
Zheng, Deng, et al.	COVID19 diagnosis	Not applicable	Neural net (DeCovNet)
Prognosis			
0			
Bai, Fang, et al.	Deterioration into severe/critical disease (period unspecified)	Combination of demograpics, signs and symptoms, laboratory results and features derived from CT images	Neural net (Multilayer perceptron + long short term memory vs. logistic regression, linear discriminant analysis, support vector machine, multilayer perceptron)
Caramelo, Ferreira, et al.	Mortality (period unspecified) *2	Age; sex; presence of any comorbidity (hypertension, diabetes, cardiovascular disease, chronic respiratory disease, cancer) *3	Logistic regression
Gong, Ou, et al.	Severe COVID-19 infection (minimum 15 day)	Age, serum LDH, CRP, variation of red blood cell distribution width, blood urea nitrogen, albumin, direct bilirubin	LASSO followed by logistic regression (vs. LASSO followed by decision tree, random forest or support vector machine)
Lu, Hu, et al.	Mortality (12 day)	Age; C-reactive protein	Cox regression
Qi, Jiang, et al	Hospital stay >10 days	6 features derived from CT images *3	Logistic regression
Qi, Jiang, et al	Hospital stay >10 days	6 features derived from CT images *3	Tree-based (random forest)
Shi, Yu, et al.	Death or severe COVID-19 (period unspecified)	Age (dichotomized); sex; hypertension	Multivariate model (not specified)
Xie, Hungerford, et al.	Mortality (in hospital)	Age, LDH, lymphocyte count, SPO2	Logistic regression
Yan, Zhang, et al.	Mortality (period unspecified)	Lactic dehydrogenase; lymphocyte count; high- sensitivity C-reactive protein	Tree-based (XGBoost)
Yuan, Yin, et al.	Mortality (period unspecified)	Clinical scorings of CT images (zone, left/right, location, attenuation, distribution of affected parenchyma)	NA (external validation)

 Image: parenchyma

 \*1 Proxy events used: pneumonia (except from TB), influenza, acute bronchitis, or other specified upper respiratory infections (no COVID-19 pneumonia cases in data).

 \*2 Outcome and pedictor data were simulated.

 \*3 Wavelet-HLH\_gldm\_SmallDependenceLowGrayLevelEmphasis, wavelet-LHH\_glcm\_Correlation, wavelet-LHL\_glszm\_GrayLevelV ariance, wavelet-LLH\_glszm\_SizeZoneNonUniformityNormalized, wavelet-LLH\_glszm\_SmallAreaEmphasis, wavelet-LLH\_glszm\_Correlation.