The Correlation of Chest X-Ray Characteristics and Severity Scores with Clinical Outcomes in COVID-19 Pneumonia Patients

ความสัมพันธ์ระหว่างลักษณะและคะแนนความรุนแรงของภาพรังสีทรวงอก
กับผลลัพธ์ทางคลินิกของผู้ป่วยที่มีภาวะปอดอักเสบจากการติดเชื้อโควิด-19

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Introduction

- Coronavirus disease (COVID-19)
    - Caused by the **SARS-CoV-2 virus**
    - ➔ Mild to moderate respiratory illness
    - ➔ More likely to develop serious illness
        - Older people + Underlying medical conditions
        (e.g., cardiovascular disease, diabetes, etc.)

Introduction

- CXR findings related to COVID-19
  - Multifocal bilateral, peripheral opacities
  - Opacities with rounded morphology
  - Lower lung–predominant distribution

Litmanovich DE et al. Journal of Thoracic Imaging. 2020;35(6):354-60.
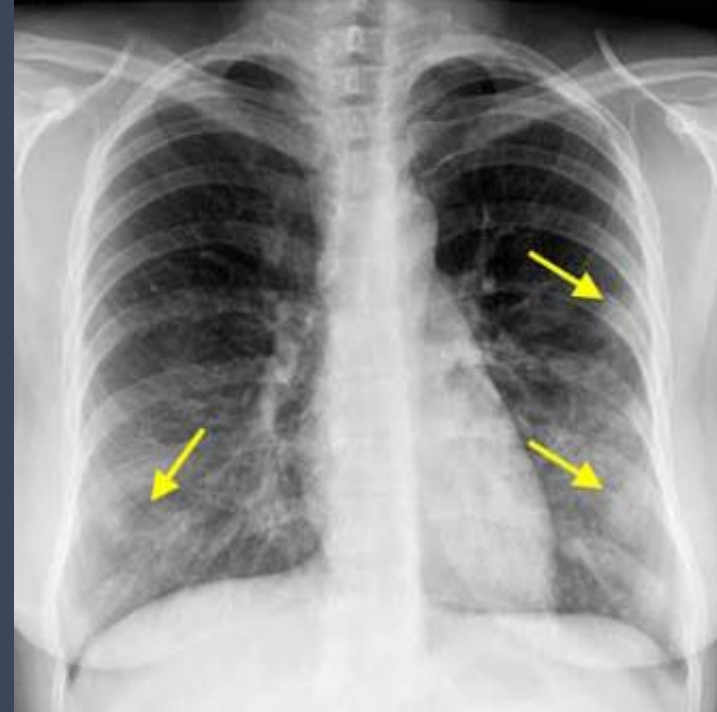
Objectives

- Describe the patient & CXR characteristics and severity scores
- Evaluate the correlation of patient & CXR characteristics and severity scores with clinical outcomes

Materials and Methods

Patients

Image acquisition

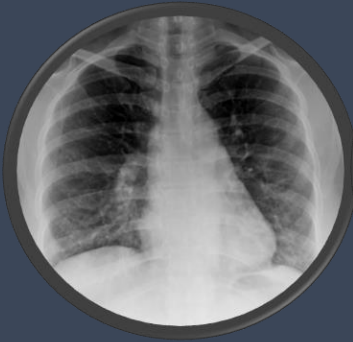Image assessment

Statistical analyses

Patients

- Retrospective descriptive study

- **Patients with COVID-19 pneumonia** at Angthong Hospital

  (1 January - 31 December 2021)

  18 years or older

- **305 patients**

  - 57   patients = Moderate pneumonia
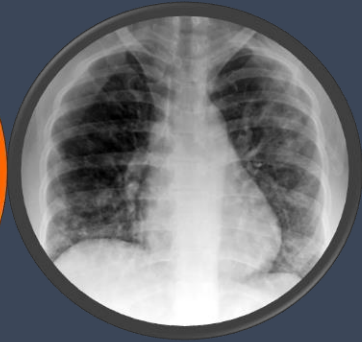
  - 248 patients = Severe pneumonia

Image acquisition

Initial CXR

HIGHEST CXR

Image assessment: CXR characteristics

Parenchymal opacity
• Consolidation
• Ground-glass opacity
• Reticular opacity

Distribution of lesion
• Peripheral
• Perihilar
• Right
• Left
• Bilateral
• Upper
• Mid
• Lower
• Diffuse

Image assessment: Severity scores

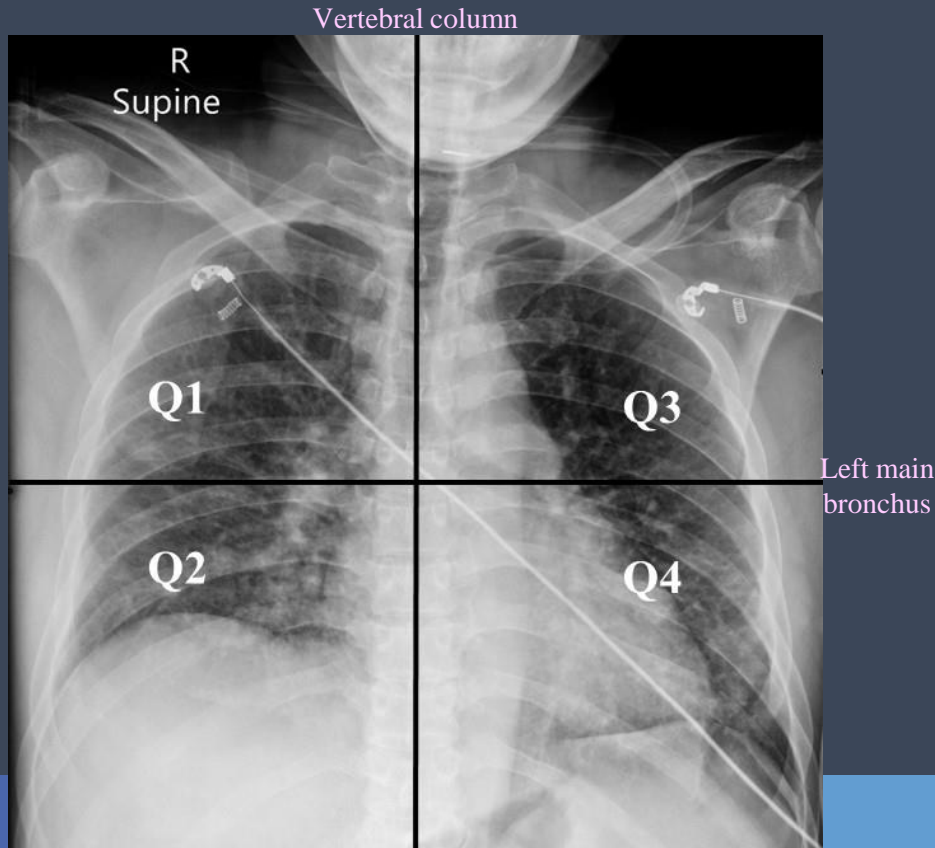### RALE score

- Radiographic Assessment of Lung Oedema (RALE) score

Brixia score

- CXR scoring system for COVID-19 pneumonia

Image assessment: RALE score

Consolidation score	Extent of alveolar opacities
0	None
1	<25%
2	25-50%
3	50-75%
4	>75%
Density score	**Density of alveolar opacities**
1	Hazy
2	Moderate
3	Dense

Cons x Den = Q score
Q1 + Q2 + Q3 + Q4

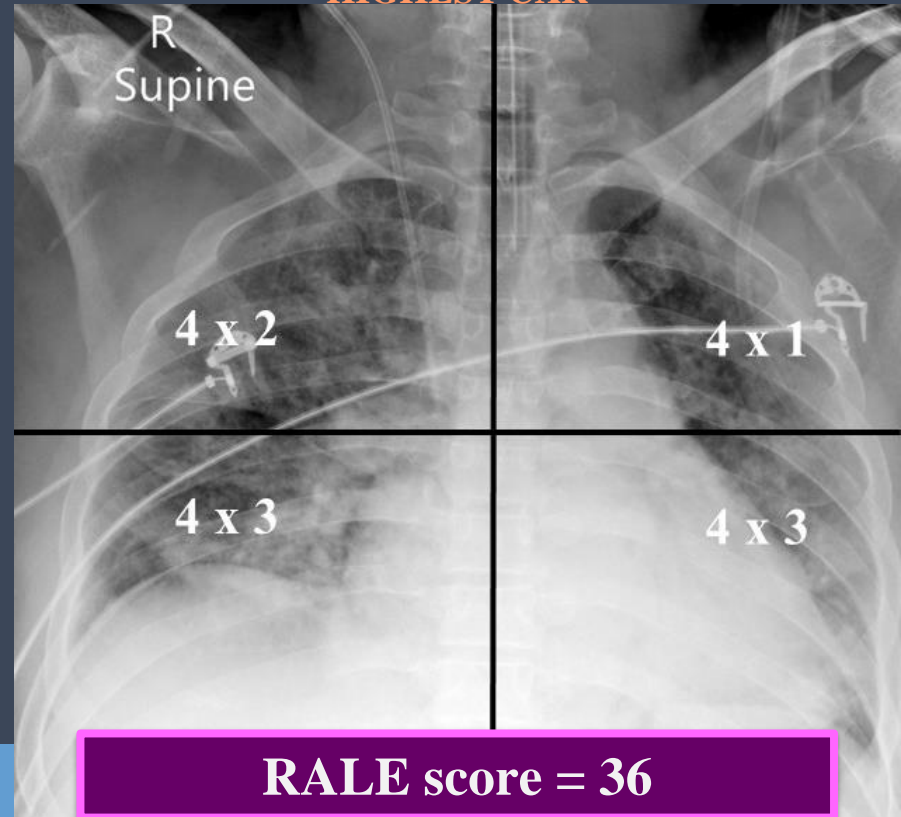**Max=48**

Image assessment: RALE score

Image assessment: Brixia score

Inf wall of aortic arch

Inf wall of RIPV

Score	Lung abnormalities
0	No lung abnormalities
1	Interstitial infiltrates
2	Interstitial and alveolar infiltrates (**interstitial** predominance)
3	Interstitial and alveolar infiltrates (**alveolar** predominance)

A + B + C + D + E + F

Max=18

Image assessment: Brixia score

Initial CXR

HIGHEST CXR

Brixia score = 10

Brixia score = 18
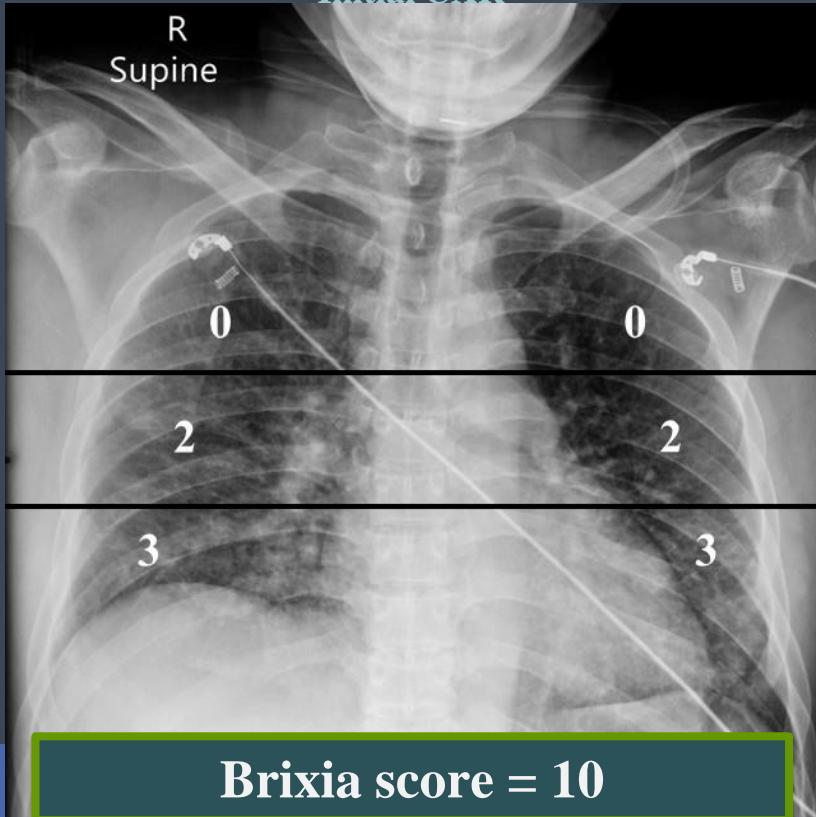
Statistical analyses

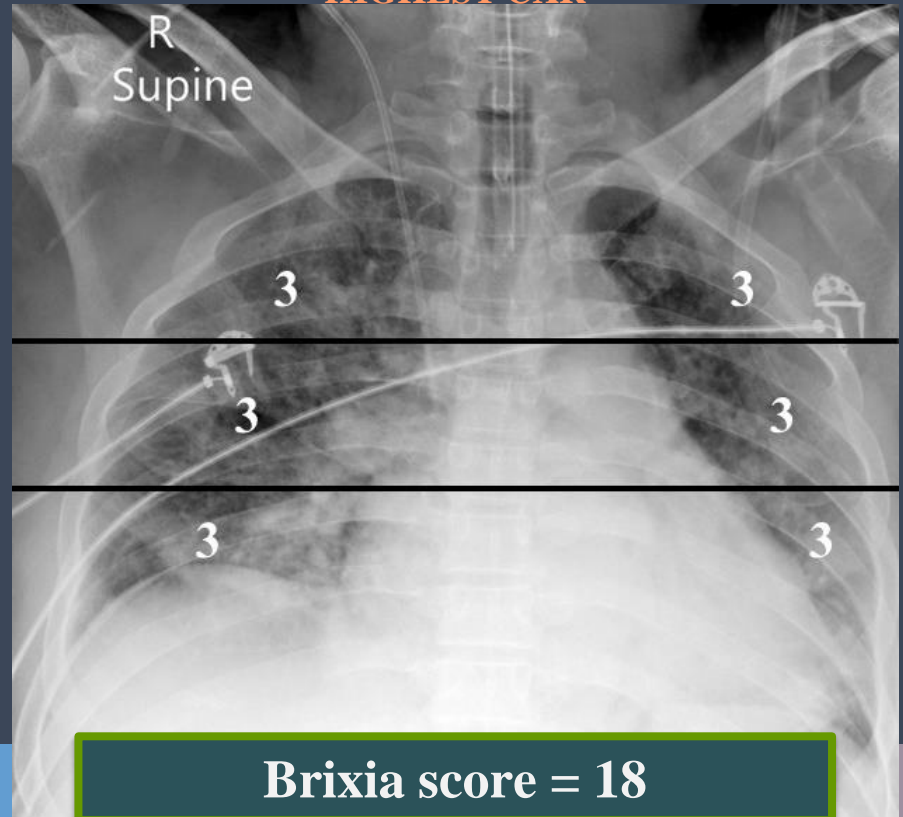- Normally and non-normally distributed data and categorical variables are presented as means ± SDs, medians with IQR, and numbers with percentages, respectively.

- Between-group differences in categorical variables were assessed using Pearson's chi-square, and continuous variables with normally and non-normally distributed data were assessed using the unpaired t-test or Wilcoxon rank-sum, respectively.

- The ROC curves and area under curves were used to determine the optimal cut-off point for severe pneumonia and mortality prediction. The performance of the test was summarized by the sensitivity, specificity, PPV, NPV, likelihood ratio, and Youden index.

- Factors associated with the severity scores were analyzed by calculating the Spearman correlation coefficient.

- Statistically significant difference was considered at p value < 0.05.

Results

Patient characteristics

CXR characteristics

Severity scores

Patient characteristics (N=305)

	Moderate group (N=57)	Severe group (N=248)	*p* value
Age, mean ±SD	52.88 ±13.59	58.43 ±14.54	0.009*
BMI ≥30 kg/m^2	29.82%	36.69%	0.309
Co-morbidities			
- DM	43.86%	48.39%	0.537
- HT	43.86%	53.63%	0.183
- Heart disease	3.51%	13.71%	0.031*

Patient characteristics (N=305)

	Moderate group (N=57)	Severe group (N=248)	p value
O₂ therapy			
- Nasal cannula	100%	0	
- HFNC	0	91.13%	NA
- ETT	0	20.97%	
O₂ therapy (days), median (IQR)	4 (3,7)	10 (7,13)	<0.001*
LOS (days), median (IQR)	12 (9,14)	16 (11,21)	<0.001*

Patient characteristics (N=305)

	Moderate group (N=57)	Severe group (N=248)	p value
Discharge type			
- Recovery	75.44%	61.69%	
- Refer to field hospital	22.81%	6.85%	
- Refer to tertiary hospital	0	2.02%	<0.001*
- Death	1.75%	29.44%	

CXR characteristics

Most common findings

- GGO
- Peripheral distribution
- Bilateral lungs
- Lower zone
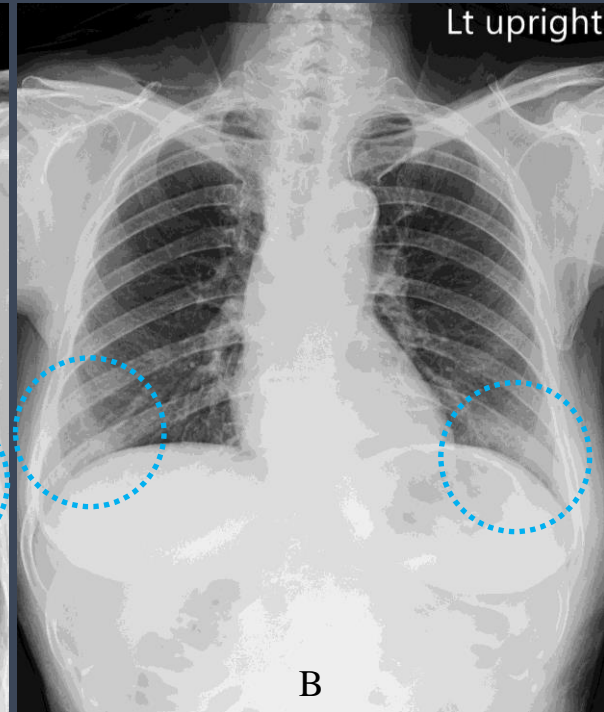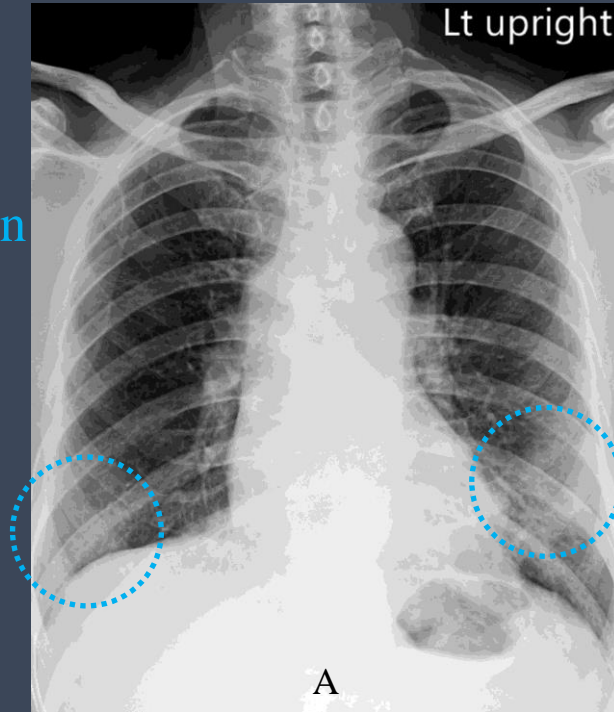
CXR characteristics

HIGHEST CXR

HIGHEST CXR

🧡 Consolidation

🧡 Perihilar distribution

🧡 Diffuse involvement
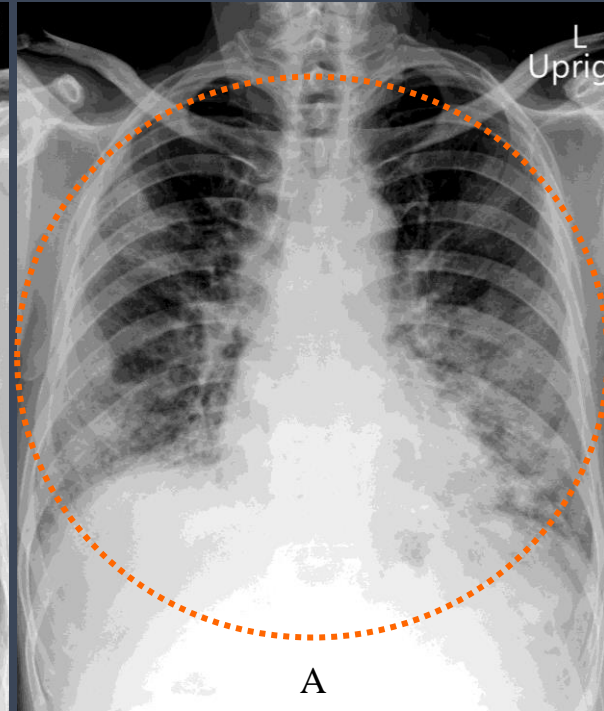
Severity scores

	Initial CXR (N=240)			HIGHEST CXR (N=304)		
	Moderate (N=55)	**Severe** (N=185)	*p* value	**Moderate** (N=57)	**Severe** (N=247)	*p* value
- RALE, median (IQR)	4.5 (2,12)	**8** (1,17)	0.268	13 (6.5,19.5)	**25** (17,34)	<0.001*
- Brixia, median (IQR)	6 (3,9)	**9** (3,12)	0.248	11.5 (6.5,13)	**15** (12,18)	<0.001*

ROC curve analysis of Severity scores of *Initial CXR* to predict Severe pneumonia.

AUC=0.55
RALE

Area under ROC curve = 0.5494

AUC=0.55
Brixia

Area under ROC curve = 0.5514
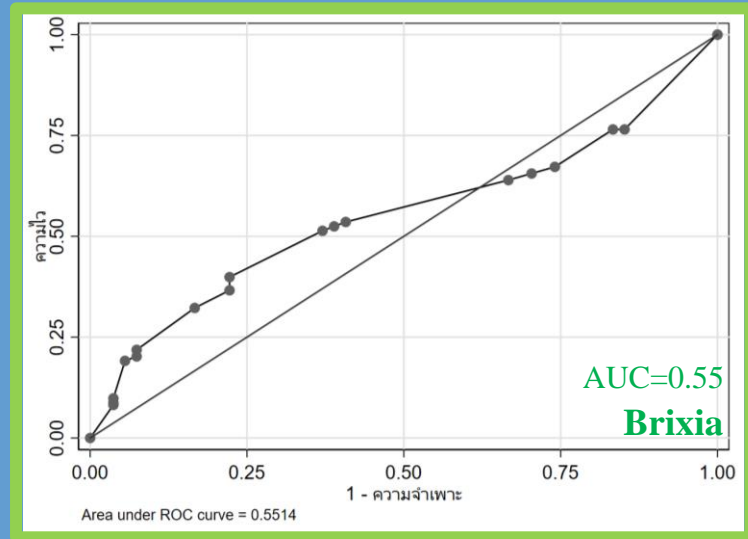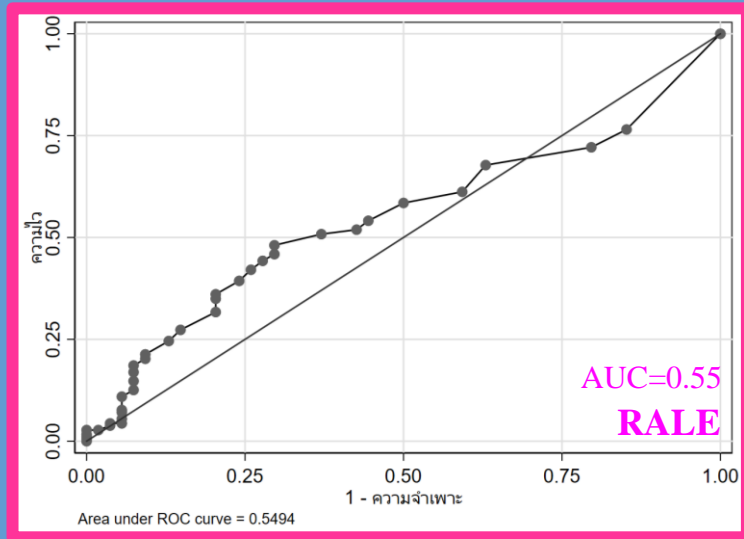
Cut-off point	Sensitivity %	Specificity %	Correct classified	LR+	LR-	Youden index
RALE ≥9	**48.09%**	**70.37%**	**53.16%**	**1.623**	**0.738**	**0.185**
Brixia ≥10	**39.89%**	**77.78%**	**48.52%**	**1.795**	**0.772**	**0.177**

ROC curve analysis of Severity scores of *Initial CXR* to predict **Mortality**.

AUC=0.60
RALE

Area under ROC curve = 0.6046

AUC=0.61
Brixia

Area under ROC curve = 0.6130
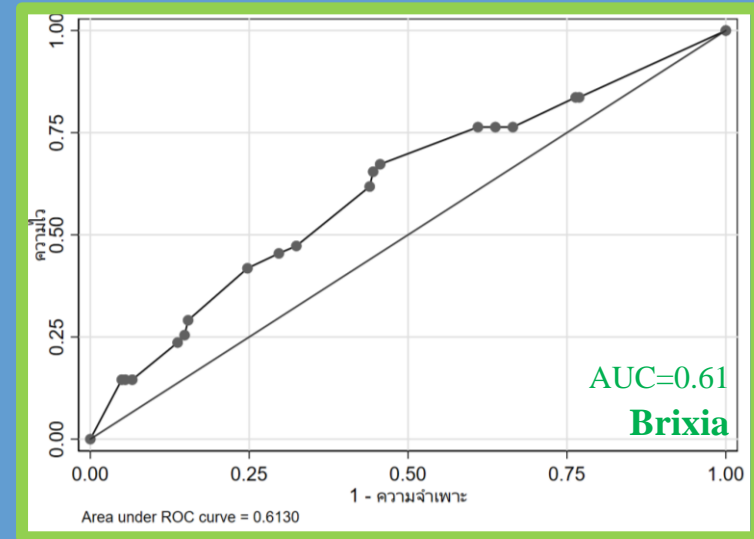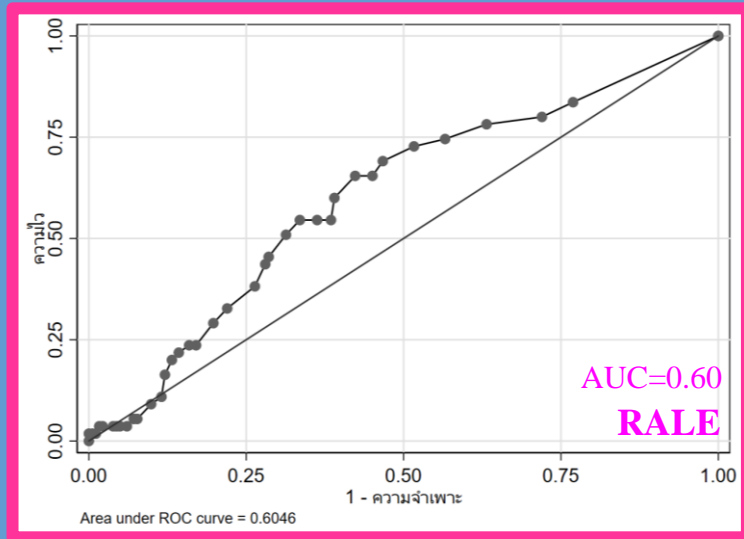
Cut-off point	Sensitivity %	Specificity %	Correct classified	LR+	LR-	Youden index
RALE ≥8	65.45%	57.69%	59.49%	1.547	0.599	0.231
Brixia ≥7	67.27%	54.40%	54.85%	1.315	0.784	0.217

	Initial RALE	Initial Brixia	HIGHEST RALE	HIGHEST Brixia	O$_2$ therapy (days)	ETT (days)
Initial Brixia	rho=0.927 n=237 $p<0.001$					
HIGHEST RALE	rho=0.396 n=236 $p<0.001$	rho=0.330 n=236 $p<0.001$				
HIGHEST Brixia	rho=0.282 n=236 $p<0.001$	rho=0.314 n=236 $p<0.001$	rho=0.755 n=301 $p<0.001$			
O$_2$ therapy (days)	rho=-0.015 n=237 $p=0.819$	rho=-0.039 n=237 $p=0.550$	rho=0.262 n=301 $p=<0.001$	rho=0.186 n=301 $p=0.001$		
ETT (days)	rho=0.282 n=237 $p=<0.001$	rho=0.291 n=237 $p<0.001$	rho=0.075 n=301 $p=0.193$	rho=0.318 n=301 $p<0.001$	rho=-0.047 n=305 $p=0.410$	
LOS	rho=-0.224 n=237 $p=<0.001$	rho=-0.259 n=237 $p<0.001$	rho=0.075 n=301 $p=0.193$	rho=0.039 n=301 $p=0.498$	rho=0.674 n=305 $p=0.001$	rho=-0.245 n=305 $p<0.001$

Results summary:

Initial RALE	☺☺☺☺☺	Initial Brixia
HIGHEST RALE	☺☺☺☺	HIGHEST Brixia
Initial RALE	☺☺	HIGHEST RALE
Initial Brixia	☺☺	HIGHEST Brixia
Initial RALE + Brixia scores	☺	ETT
	☺	LOS
	☹	O$_2$ therapy

The correlation of the Initial & Highest severity scores with Clinical outcomes
(Spearman correlation)

Discussion and Conclusion

Discussion: CXR characteristics

Our study	HIGHEST CXR (N=304)		
	Moderate (N=57)	**Severe** (N=247)	*p* value
- Perihilar	47.37%	71.66%	<0.001*

Colman et al.	Survivors (N=118)	Non-survivors (N=43)	*p* value
Ground glass opacification			
- Perihilar	16.9%	37.2%	0.0098*
- Mid zone	42.4%	62.8%	0.0318*

⬆ Severity

⬆ Mortality

Discussion: RALE score

RALE score	Cut-off point		Sens	Spec	PPV	NPV
Our study	**≥9** *(Initial CXR)*	**Severe pneumonia**	48.09%	70.37%	84.60%	28.60%
Zimatore et al.	**10**	**ARDS**	100%	71%	51%	100%

Discussion: RALE score

RALE score	Cut-off point		Sens	Spec	PPV	NPV
Our study	**≥8** *(Initial CXR)*	**Mortality**	65.45%	57.69%	31.90%	84.70%
			Adjusted RR 1.18 % (95% CI 1.07-1.31%)			
Valk et al.	**For every point increase** in the RALE score over time **the risk of death increased by 3%** (95% CI 1–5%)					

Discussion: Brixia score

Brixia score	Outcome	CXR	Median (IQR)	Score
Our study	Severe pneumonia	Initial CXR	**9** (3,12)	-
Setiawati et al.	Severe pneumonia	Initial CXR	-	7
Au-Yong et al.	Died	Baseline CXR	8 (3,12)	-
Maroldi et al.	Decease	Admission	9 (6,12)	-
Our study	Severe pneumonia	HIGHEST CXR	**15** (12,18)	-
Maroldi et al.	Decease	Highest	14 (11.8,16)	-

Discussion: Brixia score

Brixia score	Cut-off point		Sens	Spec	PPV	NPV
Our study	**≥7** *(Initial CXR)*	**Mortality**	67.27%	54.40%	30.80%	84.60%
			Adjusted RR 1.16 % (95% CI 1.04-1.29%)			
Agrawal et al.	Brixia score **more than 12** was associated with **increased mortality** due to COVID-19 (*p* value 0.03).					

Discussion

Limitation

- Retrospective descriptive study
- Single center study

Conclusion

CXR

Severity scores

➡ Severe pneumonia
➡ LOS (days)
➡ ETT (days)
➡ Mortality

RALE ≥ 8
Initial CXR
Brixia ≥ 7

> Mortality prediction

Reference

1. Coronavirus disease (COVID-19) [Available from: https://www.who.int/health-topics/coronavirus#tab=tab_1.
2. Kwee TC, Kwee RM. Chest CT in COVID-19: What the Radiologist Needs to Know. RadioGraphics. 2020;40(7):1848-65.
3. Litmanovich DE, Chung M, Kirkbride RR, Kicska G, Kanne JP. Review of Chest Radiograph Findings of COVID-19 Pneumonia and Suggested Reporting Language. Journal of Thoracic Imaging. 2020;35(6):354-60.
4. Au-Yong I, Higashi Y, Giannotti E, Fogarty A, Morling JR, Grainge M, et al. Chest Radiograph Scoring Alone or Combined with Other Risk Scores for Predicting Outcomes in COVID-19. Radiology. 2022;302(2):460-9.
5. Cecchini S, Di Rosa M, Soraci L, Fumagalli A, Misuraca C, Colombo D, et al. Chest X-ray Score and Frailty as Predictors of In-Hospital Mortality in Older Adults with COVID-19. J Clin Med. 2021;10(13).
6. Colman J, Zamfir G, Sheehan F, Berrill M, Saikia S, Saltissi F. Chest radiograph characteristics in COVID-19 infection and their association with survival. European Journal of Radiology Open. 2021;8:100360.
7. Hoang SV, Nguyen KM, Huynh TM, Huynh KLA, Nguyen PH, Tran HPN. Chest X-ray Severity Score as a Putative Predictor of Clinical Outcome in Hospitalized Patients: An Experience From a Vietnamese COVID-19 Field Hospital. Cureus. 2022;14(3):e23323.
8. Kaleemi R, Hilal K, Arshad A, Martins RS, Nankani A, Tu H, et al. The association of chest radiographic findings and severity scoring with clinical outcomes in patients with COVID-19 presenting to the emergency department of a tertiary care hospital in Pakistan. PLoS One. 2021;16(1):e0244886.
9. Maroldi R, Rondi P, Agazzi GM, Ravanelli M, Borghesi A, Farina D. Which role for chest x-ray score in predicting the outcome in COVID-19 pneumonia? Eur Radiol. 2021;31(6):4016-22.

Reference

10. Nishant Agrawal SDC, Prashant Jedge, Shivakumar Iyer, John Dsouza. Brixia Chest X-ray Scoring System in Critically Ill Patients with COVID-19 Pneumonia for Determining Outcomes. Journal of Clinical and Diagnostic Research. 2021;15(8):OC15-OC7.

11. Reeves RA, Pomeranz C, Gomella AA, Gulati A, Metra B, Hage AN, et al. Performance of a Severity Score on Admission Chest Radiography in Predicting Clinical Outcomes in Hospitalized Patients With Coronavirus Disease (COVID-19). AJR Am J Roentgenol. 2021;217(3):623-32.

12. Sathi S, Tiwari R, Verma S, Kumar Garg A, Singh Saini V, Kumar Singh M, et al. Role of Chest X-Ray in Coronavirus Disease and Correlation of Radiological Features with Clinical Outcomes in Indian Patients. Can J Infect Dis Med Microbiol. 2021;2021:6326947.

13. Shen B, Hoshmand-Kochi M, Abbasi A, Glass S, Jiang Z, Singer AJ, et al. Initial chest radiograph scores inform COVID-19 status, intensive care unit admission and need for mechanical ventilation. Clin Radiol. 2021;76(6):473.e1-.e7.

14. Singh A, Lim YH, Annamalaisamy R, Koteyar SS, Chandran S, Kanodia AK, et al. Chest x-ray scoring as a predictor of COVID-19 disease; correlation with comorbidities and in-hospital mortality. Scottish Medical Journal. 2021;66(3):101-7.

15. Warren MA, Zhao Z, Koyama T, Bastarache JA, Shaver CM, Semler MW, et al. Severity scoring of lung oedema on the chest radiograph is associated with clinical outcomes in ARDS. Thorax. 2018;73(9):840-6.

16. Borghesi A, Maroldi R. COVID-19 outbreak in Italy: experimental chest X-ray scoring system for quantifying and monitoring disease progression. Radiol Med. 2020;125(5):509-13.

17. A minimal common outcome measure set for COVID-19 clinical research. Lancet Infect Dis. 2020;20(8):e192-e7.

Reference

18. Hansell DM, Bankier AA, MacMahon H, McLoud TC, Müller NL, Remy J. Fleischner Society: Glossary of Terms for Thoracic Imaging. Radiology. 2008;246(3):697-722.

19. Setiawati R, Widyoningroem A, Handarini T, Hayati F, Basja AT, Putri A, et al. Modified Chest X-Ray Scoring System in Evaluating Severity of COVID-19 Patient in Dr. Soetomo General Hospital Surabaya, Indonesia. Int J Gen Med. 2021;14:2407-12.

20. Wong HYF, Lam HYS, Fong AH-T, Leung ST, Chin TW-Y, Lo CSY, et al. Frequency and Distribution of Chest Radiographic Findings in Patients Positive for COVID-19. Radiology. 2020;296(2):E72-E8.

21. Martínez Chamorro E, Díez Tascón A, Ibáñez Sanz L, Ossaba Vélez S, Borruel Nacenta S. Radiologic diagnosis of patients with COVID-19. Radiologi´a. 2021;63(1):56-73.

22. Nagpal P, Narayanasamy S, Vidholia A, Guo J, Shin KM, Lee CH, et al. Imaging of COVID-19 pneumonia: Patterns, pathogenesis, and advances. Br J Radiol. 2020;93(1113):20200538.

23. Zimatore C, Pisani L, Lippolis V, Calfee CS, Ware LB, Algera AG, et al. The radiographic assessment of lung edema (RALE) score has excellent diagnostic accuracy for ARDS. European Respiratory Journal. 2019;54(suppl 63):OA3299.

24. Zimatore C, Pisani L, Lippolis V, Warren MA, Calfee CS, Ware LB, et al. Accuracy of the Radiographic Assessment of Lung Edema Score for the Diagnosis of ARDS. Frontiers in Physiology. 2021;12.

25. Valk CMA, Zimatore C, Mazzinari G, Pierrakos C, Sivakorn C, Dechsanga J, et al. The Prognostic Capacity of the Radiographic Assessment for Lung Edema Score in Patients With COVID-19 Acute Respiratory Distress Syndrome-An International Multicenter Observational Study. Front Med (Lausanne). 2022;8:772056-.