Original Article

Predicting Pneumonia in Acute Ischaemic Stroke: Comparison of Five Prediction Scoring Models

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Abstract

Introduction: Although pneumonia is a major complication after acute ischaemic stroke (AIS), pneumonia prediction scores have not been extensively validated. This study aimed to compare the discrimination performance of 5 pneumonia prediction scores in AIS patients. Materials and Methods: We retrospectively reviewed all consecutive adult AIS patients whom presented to our emergency department within 4.5 hours of symptom-onset between January 2012 and February 2015. Diagnosis had to be made by a neurologist and infarcts confirmed by neuroimaging. We excluded patients with pneumonia on presentation. Pneumonia predictors were based on the 5 prediction scoring models: Kwon's score, Chumbler's score, Acute Ischaemic Stroke-Associated Pneumonia Score (AIS-APS), A^2DS^2 score and ISAN score. The definition of stroke-associated pneumonia was based on the criteria by the Pneumonia in Stroke Consensus Group. Analysis using area under receiver operating characteristics curve (AUROC) was performed. Results: Forty (5.5%) out of 731 patients analysed had stroke-associated pneumonia (SAP). A^2DS^2 score had the highest discrimination capacity (AUROC 0.88; 95% CI, 0.84 to 0.92), followed by AIS-APS (AUROC 0.87; 95% CI, 0.83 to 0.91), Kwon's score (AUROC 0.86; 95% CI, 0.82 to 0.92), Prestroke Independence, Sex, Age and National Institutes of Health Stroke Scale (ISAN) score (AUROC 0.85; 95% CI, 0.80 to 0.90) and Chumbler's score (AUROC 0.79; 95% CI, 0.74 to 0.84). However, there was no statistical difference of discrimination capacity among A^2DS^2 score, AIS-APS and Kwon's score. Conclusion: A^2DS^2, AIS-APS and Kwon's scores performed comparably in discriminating SAP in AIS patients.

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Key words: Prognosis, Epidemiology, Retrospective studies, Validation, Singapore, Brain ischaemia/complications

Introduction

Pneumonia is a major cause of mortality, prolonged hospital stay and poor functional outcome when occurring immediately after acute ischaemic stroke (AIS).[1-3] Pneumonia is also common poststroke, with incidence ranging between 9% to 56%.[3-5] Although some pharmacological and novel non-pharmacological interventions have been shown to reduce the incidence of pneumonia in post-AIS patients,[6-12] universal implementation of preventive measures in all AIS patients has not consistently improved neurological outcome or mortality.[13] A postulated reason for the failure of pneumonia prevention intervention was that the majority of stroke patients recruited in studies were at low risk of developing pneumonia.[13,14] Therefore, a reliable clinical prediction tool to identify patients at increased risk of developing pneumonia after AIS is needed in order to optimise selection of patients for early pneumonia preventive interventions.

Various different clinical factors have been shown to be associated with pneumonia after AIS.[15-19] Six pneumonia prediction scores have also been derived from different post-AIS populations. One score was exclusively derived from neurological intensive care patients[20] and was considered not applicable to our study population. The 5 pneumonia

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prediction scores evaluated in this study were Kwon's score,[21] Chumbler's score,[22] A^2DS^2 score,[23] Acute Ischaemic Stroke-Associated Pneumonia Score (AIS-APS)[24] and the Prestroke Independence, Sex, Age and National Institutes of Health Stroke Scale (ISAN) score.[25] Although these scores have been previously separately validated,[24,26,27] they have not been subjected to head-to-head comparison within a single patient population, hence it is still uncertain which score is ideal at identifying patients at high risk of developing pneumonia. Moreover, the newly developed ISAN score[25] has never been externally validated in an Asian population.

The definition of stroke-associated pneumonia (SAP) used in the derivation of the pneumonia prediction scores has been inconsistent,[4] resulting in variability of the predictive capability of these scores. To standardise the diagnostic criteria for pneumonia complicating stroke, a new operational definition of SAP was published by the Pneumonia in Stroke Consensus (PISCES) Group.[28] Recommendations for the definitions of hospital-acquired pneumonia (HAP) and ventilator-associated pneumonia (VAP) were also made.[28] In view of the changes in pneumonia definitions, there is a need to validate the predictive capabilities of existing pneumonia prediction scores with the new criteria.

The primary aim of this study was to determine the pneumonia prediction score with the highest discrimination capacity for SAP in AIS patients, using the new operational criteria of SAP recommended by PISCES. The secondary aim was to evaluate the incidence of SAP, HAP and VAP using the new definitions.

Materials and Methods

Participants

This study was performed in adults, 21 years or older, at a single acute tertiary care teaching hospital (Tan Tock Seng Hospital) in Singapore. Our hospital consists of 1200-beds and has 400 emergency attendances per day.[29] Our hospital is also Joint Commission International-accredited and houses a comprehensive stroke unit with a 24 hours in-house Neurology stroke service.

Participants for this study were obtained from an AIS registry between January 2012 and February 2015. The hospital prospectively maintains a registry of all consecutive AIS patients who present to the emergency department (ED) and whom required emergent evaluation by Neurology stroke service for suitability of thrombolysis. In clinical practice, patients who present beyond 4.5 hours were considered as "late" as they no longer qualify for intravenous thrombolysis. Hence, we used the 4.5 hours time cutoff in this study to ensure that the pneumonia occurring was a direct consequence of AIS. In addition, patients in the registry had to have radiological evidence of infarction[30] during the course of their hospitalisation, either by computed tomography (CT) of the head or magnetic resonance imaging (MRI). Patients with haemorrhagic strokes, as diagnosed via CT scan of the head performed in the ED as part of the hospital stroke protocol, were excluded from the registry. In addition, patients who were diagnosed with a stroke mimic, who suffered AIS while in hospital for other reasons, or who presented to the ED more than 4.5 hours from onset of symptoms were also excluded from the registry.

Prediction Risk Scores Variables

Medical records at presentation to ED were reviewed to collect the clinical parameters required for scoring each pneumonia prediction score (Table 1).[21-24] The variables of atrial fibrillation (AF), dysphagia status and mechanical ventilation status were retrieved from medical records during the course of hospitalisation. AF status was based on electrocardiographs or continuous cardiac monitoring (telemetry or Holter) reports obtained prior to the diagnosis of pneumonia. Dysphagia status was recorded by a trained nursing staff from the stroke unit or by a speech therapist as part of the hospital stroke protocol. Mechanical ventilation status during hospitalisation was considered only up to the point of diagnosis of pneumonia. Mechanical ventilation is considered as a separate independent variable in this study and was not considered as a dysphagia risk factor.

Outcome Measures

We used "definite" SAP[28] as the primary outcome measure of our study. "Definite" SAP required all modified Communicable Diseases Centre (CDC) criteria to be met and diagnostic chest X-ray (CXR) changes on at least 1 CXR (Table 2).[28] The secondary outcomes of HAP and VAP were also based on recommendations by PISCES Group.[28] All clinical notes, laboratory investigations and chest radiographs were reviewed to determine if the diagnostic criteria for each of the subtypes of pneumonias were fulfilled. This was conducted blinded to the clinical predictors by a single investigator (S Phua). Only the first episode of pneumonia in the course of hospitalisation was included in this analysis.

We excluded patients who were already diagnosed with pneumonia on presentation at the ED. This was because it was uncertain if the pneumonia preceded the onset of stroke and these patients could not have had their pneumonia prevented anyway. We did not exclude any patients who were intubated for neurologic reasons. Our hospital institutional review board approved this study and waiver of informed consent was approved in view of the retrospective nature of the study.

Table 1. Clinical Variables and Point Allocations of Each Scoring Algorithm

Scoring Algorithm	Clinical Variable	Assigned Points
Kwon's score	NIHSS ≥11	1
	Age ≥65 years	1
	Male	1
	Presence of mechanical ventilation	1
	Presence of dysphagia	1
Chumbler's score	Age >70 years	1
	Abnormal swallowing test	1
	Admission NIHSS Score ≥2	1
	Found down at symptom onset	1
	Past medical history of pneumonia	1
A^2DS^2 score	Age ≥75 years	1
	Atrial fibrillation	1
	Dysphagia	2
	Male	1
	NIHSS	
	0 – 4	0
	5 – 15	3
	≥16	5
AIS-APS	Age in years	
	≤59	0
	60 – 69	2
	70 – 79	5
	≥80	7
	Medical history/comorbidity	
	Atrial fibrillation	1
	Congestive heart failure	3
	Chronic obstructive pulmonary disease	3
	Current smoking	1
	Prestroke dependence (mRS ≥3)	2
	Admission NIHSS	
	0 – 4	0
	5 – 9	2
	10 – 15	5
	≥16	8
	Admission GCS score	
	9 – 15	0
	3 – 8	3
	Dysphagia	3
	OCSP subtype	
	Lacunar infarction	0
	Partial anterior circulation infarction	0
	Total anterior circulation infarction	2
	Posterior circulation infarction	2
	Admission glucose level ≥11.1 mmol/L	2
ISAN score	Age in years	
	<60	0
	60 – 69	3
	70 – 79	4
	80 – 89	6
	90 and above	8
	Sex	
	Female	0
	Male	1
	NIHSS on admission	
	0 – 4	0
	5 – 15	4
	16 – 20	8
	21 and above	10
	Prestroke mRS	
	Independent (0 – 1)	0
	Not independent (2 – 5)	2

AIS-APS: Acute ischaemic stroke-associated pneumonia score; GCS: Glasgow Coma Scale; ISAN: Prestroke Independence, Sex, Age and National Institutes of Health Stroke Scale; mRS: Modified Rankin Scale; NIHSS: National Institutes of Health Stroke Scale; OCSP: Oxfordshire Community Stroke Project

Statistical Analysis

Demographic and clinical characteristics of the study population were summarised using appropriate descriptive statistics. Risk scores and the predicted probability of pneumonia for each patient were calculated according to the 5 risk prediction models. To assess the predictive performance of each risk prediction model, a univariate logistic regression model on pneumonia were fitted by entering each risk score as a continuous variable. The model fit was checked using Hosmer-Lemeshow goodness-of-fit statistics and non-parametric calibration curves were estimated using 1000 bootstrap resampling scheme. Receiver operating characteristics (ROC) analysis was done for performance comparison. Discrimination was assessed with the area under the ROC curve (AUROC) for each prediction model; 95% confidence intervals around these AUROCs were estimated. These AUROCs were then compared pair-wise with each other using DeLong's

non-parametric test to compare 2 correlated ROC curves. No formal correction was made for multiple comparisons.

In a one-sided test comparing the AUROC of a reference test to a proposed test for discrete response data using a z-test approximation, a sample size of 40 cases and a sample size of 600 controls achieves 80% power at the 5% significance level, when the AUROC for both models under the null hypothesis is 0.75 (hypothesised from Chumber's score[22]) and the AUROC of the proposed model under the alternative hypothesis is 0.85 (hypothesised from A^2DS^2 score[23]). This assumed that the correlation between the model scores for cases is 0.9 and the correlation between controls is 0.6. Because a study population of approximately 640 patients was required, we estimated that a review of 3 years duration of our stroke registry was needed.

The optimal cutoff for each scoring algorithm was estimated from the ROC curves and was defined as the point with the maximum sum of sensitivity and specificity. For these cutoffs of each scoring algorithm, sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were estimated with their corresponding 95% confidence intervals (CI). The same analyses were done separately for the all pneumonia cases and different subtypes of pneumonia. All statistical analyses were performed in R version 3.1.2. Tests were two-sided and statistical significance was set at 5% level.

Results

A total of 746 patients were identified from our AIS registry between the period of January 2012 and February 2015. Fifteen patients were diagnosed with pneumonia on presentation, hence 731 patients were included in the final

Table 2. Definitions of Poststroke Pneumonia

Criteria	Definition
Pneumonia*	At least 1 of the following:
	-Fever (>38°C) with no other recognised cause
	-Leukopaenia (<4000 WBC/mm^3) or leukocytosis (>12,000 WBC/mm^3)
	-For adults ≥70 years old, altered mental status with no other recognised cause
	And at least 2 of the following:
	-New onset of purulent sputum, or change in character of sputum over a 24 hour period, or increased respiratory secretions, or increased suctioning requirements
	-New onset or worsening cough, or dyspnea, or tachypnea (respiratory rate >25/min)
	-Rales, crackles, or bronchial breath sounds
	-Worsening gas exchange (eg, O_2 desaturation [eg, PaO_2/FiO_2 ≤240], increased oxygen requirements)
	And ≥2 serial chest radiographs with at least 1 of the following:
	-New or progressive and persistent infiltrate, consolidation, or cavitation
SAP	Fulfills the above definition of pneumonia
	And occurs within and including the first 7 days after onset of stroke in non-ventilated patients
HAP	Fulfills the above definition of pneumonia
	And occurs after 7 days after onset of stroke in non-ventilated patients
VAP	Fulfills the above definition of pneumonia
	And occurs more than 48 hours after initiation of mechanical ventilation

CXR: Chest X-ray; FiO_2: Fraction of inspired oxygen; HAP: Hospital-acquired pneumonia; PaO_2: Partial pressure oxygen; SAP: Stroke-associated pneumonia; VAP: Ventilator-associated pneumonia; WBC: White blood cell
*In patients without underlying pulmonary or cardiac disease, 1 definitive chest radiograph is acceptable.

Table 3. Baseline Characteristics of Participants on Admission

	Study Cohort (n = 731)
Demographics	
Age group, n (%), year	
<60	215 (29.4)
60 – 69	182 (24.9)
70 – 79	192 (26.3)
≥80	142 (19.4)
Male sex, n (%)	442 (60.5)
Vascular risk factors, n (%)	
Current smokers	237 (32.4)
Atrial fibrillation	229 (31.3)
Congestive cardiac failure	61 (8.3)
Admission NIHSS score, median (IQR)	6 (2 – 16)
Admission Glasgow Coma Scale score, n (%)	
13 – 15	551 (75.4)
9 – 12	150 (20.5)
3 – 8	30 (4.1)
Admission glucose ≥11.1, n (%)	129 (17.6)
Symptom of dysphagia, n (%)	344 (47.1)
Mechanical ventilation during admission, n (%)	44 (6.0)
OCSP subtype, n (%)	
Partial anterior circulation infarct	392 (53.6)
Total anterior circulation infarct	32 (4.4)
Lacunar infarction	218 (29.8)
Posterior circulation infarct	89 (12.2)
Pneumonia classification, n (%)	
Stroke-associated pneumonia	40 (5.5)
Hospital-acquired pneumonia	29 (3.9)
Ventilator-associated pneumonia	10 (1.4)

IQR: Interquartile range; NIHSS: National Institutes of Health Stroke Scale; OCSP: Oxfordshire Community Stroke Project

Table 4. Clinical Criteria Fulfilled by Stroke-Associated Pneumonia Patients (n = 40)

	No. of Patients (% of SAP Patients)*
At least 1 of the following:	
-Fever (>38°C) with no other recognised cause	34 (85.0%)
-Leukopaenia (<4000 WBC/mm^3) or leukocytosis (>12 000 WBC/mm^3)	27 (67.5%)
-For adults ≥70 years old, altered mental status with no other recognised cause	3 (7.5%)
And at least 2 of the following:	
-New onset of purulent sputum, or change in character of sputum over a 24 hour period, or increased respiratory secretions, or increased suctioning requirements	29 (72.5%)
-New onset or worsening cough, or dyspnea, or tachypnea (respiratory rate >25/min)	28 (70.0%)
-Rales, crackles, or bronchial breath sounds	9 (22.5%)
-Worsening gas exchange	17 (42.5%)
And ≥2 serial chest radiographs† with at least 1 of the following:	
-New or progressive and persistent infiltrate, consolidation, or cavitation	40 (100%)

SAP: Stroke-associated pneumonia; WBC: White blood cells
*The number of SAP patients ≥70 years old = 30 (75% of SAP patients).
†In patients without underlying pulmonary or cardiac disease, 1 definitive chest radiograph is acceptable.

analysis. Characteristics of included patients are summarised in Table 3. Using the PISCES definition, 40 (5.5%) patients were diagnosed with SAP, and 29 (3.9%) with HAP and 10 (1.4%) with VAP. A total of 79 (10.8%) patients were diagnosed with any form of pneumonia. The median onset of SAP was on day 4. A summary of the clinical criteria fulfilled by SAP patients is shown in Table 4.

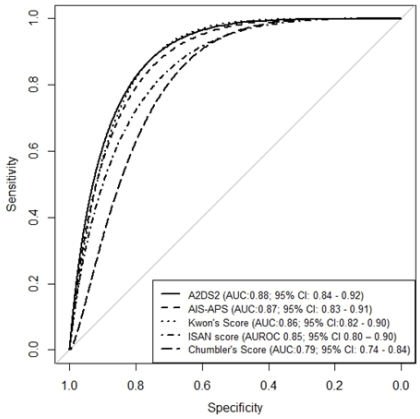

Fig. 1. Receiver operating characteristics curve for stroke-associated pneumonia. The plot of sensitivity (y-axis) versus decremental specificity (x-axis) demonstrates A^2DS^2 with maximal area under curve. AIS-APS indicates acute ischaemic stroke-associated pneumonia score. AUC: Area under curve; CI: Confidence interval; ISAN: Prestroke Independence, Sex, Age and National Institutes of Health Stroke Scale; ROC: Receiver operating characteristics.

A^2DS^2 score had the highest discrimination capacity for SAP (AUROC 0.88; 95% CI, 0.84 to 0.92), followed by AIS-APS (AUROC 0.87; 95% CI, 0.83 to 0.91), Kwon's score (AUROC 0.86; 95% CI, 0.82 to 0.92), ISAN score (AUROC 0.85; 95% CI, 0.80 to 0.90), and Chumbler's score (AUROC 0.79; 95% CI, 0.74 to 0.84) (Fig. 1) in decreasing order. A^2DS^2 score also had the highest discrimination for HAP (AUROC 0.86; 95% CI, 0.80 to 0.93) and any form of pneumonia (AUROC 0.86; 95% CI, 0.82 to 0.90) (Fig. 2) compared to the rest. Although there were only 10 VAP patients, Kwon's score provided the best discrimination for VAP (AUROC 0.94; 95% CI, 0.89 to 0.98) (Fig. 2). However, despite A^2DS^2 outperforming the other scores, there was no statistical difference of discriminating capacity for SAP among A^2DS^2 score, AIS-APS and Kwon's score (Table 5).

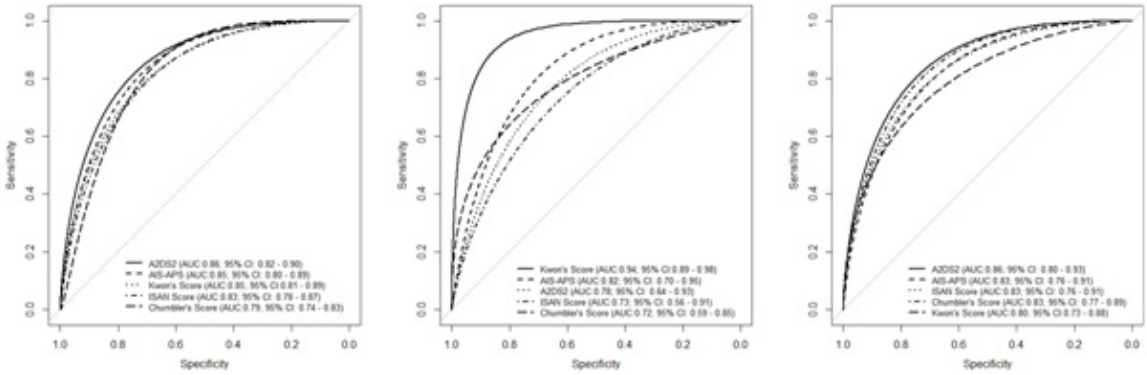

Fig. 2. Receiver operating characteristics curves for all forms of pneumonia (left), ventilator-associated pneumonia (centre) and hospital-acquired pneumonia (right). The plots of sensitivity (y-axis) versus decremental specificity (x-axis) demonstrating maximal area under curve for A^2DS^2 score for any form of pneumonia (left) and hospital-acquired pneumonia (right). Kwon's score had the maximal area under curve for ventilator-associated pneumonia (centre). AIS-APS: Acute ischaemic stroke-associated pneumonia score; AUC: Area under curve; CI: Confidence interval; ISAN: Prestroke Independence, Sex, Age and National Institutes of Health Stroke Scale; ROC: Receiver operating characteristics.

Table 5. Pair-Wise Comparison of Discrimination Capacity for Stroke-Associated Pneumonia

	ΔAUROC*	*P* Value†	ΔAUROC*	*P* Value†	ΔAUROC*	*P* Value†	ΔAUROC*	*P* Value†
Stroke associated pneumonia (n = 40)								
A^2DS^2 score	Ref.							
AIS-APS	0.011	0.493	Ref.					
Kwon's score	0.025	0.216	0.015	0.526	0.526			
ISAN score	0.033	0.045	0.023	0.173	0.173	0.779	Ref.	
Chumbler's score	0.091	<0.001	0.081	<0.001	<0.001	0.015	0.058	0.049

AIS-APS: Acute ischaemic stroke-associated pneumonia score; AUROC: Area under the receiver operating characteristic curve; ISAN: Prestroke Independence, Sex, Age and National Institutes of Health Stroke Scale

*ΔAUROC denotes the difference in AUROC between the reference algorithm indicated and the algorithm listed in each row.

†*P* values are from DeLong's test for 2 correlated ROC curves.

All scores had similarly high NPV (98% to 100%) but relatively low PPV (9% to 20%). The optimal cutoff scores for SAP, with the maximum sum of sensitivity and specificity, for A^2DS^2 was 7. The estimated risk from all 4 models showed acceptable agreement with the observed rate of SAP (all non-significant *P* values for Hosmer-Lemeshow test), and A^2DS^2 provided the best agreement. The calibration curves matched well with AUROC measures for other pneumonia subtypes, Kwon's score being the best risk prediction model for VAP and all 3 other models providing good calibration for HAP (Table 6).

Discussion

The present study is the first to compare 5 pneumonia scoring models using an AIS patient cohort. A^2DS^2 score was able to predict SAP with the highest discrimination capacity among all scoring algorithms assessed and also had the best agreement between the predicted and observed rate of SAP. A^2DS^2 also performed similarly well for HAP and any form of pneumonia, albeit at a different cutoff score. Despite the above, it must be noted that there was no statistical difference of discrimination capacity for SAP among A^2DS^2 score, AIS-APS and Kwon's score. This implies that although A^2DS^2 performed best in our cohort, the differences of discrimination capacity among AIS-APS and Kwon's score were small. Therefore, the choice of which prediction algorithm to use clinically will depend greatly on its ease of use. Among the above 3 similarly performing predictions models, both A^2DS^2 and Kwon's scores requires only 5 clinical variables while AIS-APS requires 8, therefore possibly favouring the former 2 over the latter in terms of practical utility.

Chumbler's score had the lowest discrimination capacity and was significantly lower compared to all other scores evaluated. The lower discrimination capacity and difference in cutoffs[24] may be due to different methodology used for scoring the risk factors as we used the number of risk factors present instead of the odds ratio of risk factors.[22] ISAN score only performed marginally poorer to A^2DS^2 score ($P = 0.045$) and was equivalent to AIS-APS and Kwon's score. This is most likely because ISAN score only required 4 variables[25] in its algorithm, less than the other scoring models, contributing to its lower discrimination capacity. In addition, our study provides the first report that ISAN score may not perform as well in an Asian cohort compared to other populations.[27]

Table 6. Performance Statistics for Stroke-Associated Pneumonia

Prediction Model	Cutoff	Sensitivity (%) (95% CI)	Specificity (%) (95% CI)	PPV (%) (95% CI)	NPV (%) (95% CI)	No. of Cases of SAP Above Cutoff	No. of Patients Above Cutoff	Percentage of Patients Below Cutoff	Hosmer-Leme-show Statistic (*P* Value), No. of Groups
A^2DS^2 score	7	90 (80 – 97)	75 (71 – 78)	18 (16 – 21)	99 (98 – 100)	36	231	68.4	0.75 (0.999), 10
AIS-APS	11	95 (87 – 100)	66 (62 – 69)	15 (13 – 16)	99 (98 – 100)	38	294	59.8	5.03 (0.169), 5
Kwon's score	3	92 (82 – 100)	71 (68 – 75)	17 (15 – 19)	99 (98 – 100)	37	256	65.0	8.60 (0.072), 6
ISAN score	11	83 (70 – 92)	80 (77 – 83)	20 (17 – 23)	98 (97 – 99)	33	191	73.9	2.39 (0.303), 4
Chumbler's score	2	100 (100 – 100)	38 (34 – 41)	9 (8 – 10)	100 (100 – 100)	40	484	33.8	3.52 (0.061), 3

AIS-APS: Acute ischaemic stroke-associated pneumonia score; CI: Confidence interval; ISAN: Prestroke Independence, Sex, Age and National Institutes of Health Stroke Scale; PPV: Positive predictive value; NPV: Negative predictive value; SAP: Stroke-associated pneumonia

All scoring algorithms had low PPV for SAP at their respective optimal cutoff scores, indicating that all these scores do not perform well if used to select an at-risk population. For the purpose of identifying high-risk patients, a higher PPV will be required, thereby requiring a higher, but less optimal, cutoff for each score. Despite adjusting the cutoffs to the highest risk group, the highest PPV remains a modest 29.1% (7 out of 24 patients for A^2DS^2 score at the cutoff of 10). Interestingly, all 4 scoring algorithms had very high NPV (range, 98 to 100%), suggesting that all these scores are better utilised to exclude patients unlikely to develop SAP, rather than to include them. By excluding patients below the optimal cutoff scores, a reduction of approximately 60% to 68% of patients at low risk of pneumonia (using A^2DS^2 score, AIS-APS or Kwon's score) may be achieved without significantly compromising the number of SAP detected (Table 6). This is very helpful to reduce unnecessary patient recruitment for pneumonia prevention trials.

The discrimination capacity for SAP was higher in our study population compared to previously published data on the same scores.[22-24,31] Possible reasons for higher AUROC results include stricter definition of pneumonia used resulting in less variance in the outcome, different cutoffs for each of the scores used from those previously published,[24] and a more homogenous population studied due to early presentation at the ED.

The low incidence of SAP (5.5%) is an important consideration for future researchers using the new SAP definition. If we included the 15 patients excluded from our study due to the diagnosis of pneumonia on presentation, the incidence of SAP would only be 7.5%. It is to be noted that we used the stricter "definite" SAP definition and not the "probable" SAP as an endpoint in our study as we wanted radiological evidence as proof of pneumonia. The use of the more lenient "probable" SAP may increase the incidence of pneumonia and warrants further investigation. Moreover, the diagnosis of pneumonia before stroke is likely underestimated in a retrospective design, hence the true SAP rates may be higher than 7.5%. Nevertheless, the incidence of any form of pneumonia in our study (10.8%) was comparable to other study cohorts,[3] hence the incidence of "definite" SAP would likely be similar in other populations.

The stroke severity of our study population (median National Institutes of Health Stroke Scale [NIHSS] = 6) was similar to the stroke severity of all reference prediction scores (median NIHSS 4-7).[22-25] This suggests that our study population was representative of a general stroke population and all the prediction scores could be applied to our study cohort. Nevertheless, the stroke severity in our study population was relatively mild, hence the inference of our results in severe strokes is unclear and deserves further evaluation.

The main limitation of our study was the retrospective design. Completeness of chart records and inter-observer variations of the clinical variables could not be ascertained. Incomplete symptomatology clinical records may have underestimated the pneumonia rates. Nevertheless, dysphagia assessment records, temperature records and investigations (blood and radiological) were complete for all patients. Inherent to a retrospective study, judgement error and systematic bias during data retrieval by a single blinded observer may be introduced due to the absence of a second blinded independent observer. However, we attempted to reduce this reporting bias by using objective data when interpreting clinical information as often as possible, such as an independent chest radiograph report. We did not correct for differences in management prior to the diagnosis of pneumonia that could have possibly influenced the development of pneumonia. These potentially included nursing techniques,[6] antibiotics or other medication use.[10,11,32] We also did not collect information with regard to the aetiology of the stroke which may have influenced the incidence of SAP. However, the aim of the study was to use clinical information available on presentation to predict pneumonia development during hospitalisation, hence these clinical factors were not collected. Lastly, as we only included patients who presented within 4.5 hours from onset of stroke to the ED for this study, therefore possibly limiting the generalisability of our results. In the general stroke population, less than half of AIS patients arrive within 4.5 hours from onset of their symptoms to the ED.[33] Therefore, the discrimination capacity of these algorithms in patients who presents late to the hospital remains uncertain.

The main strength of our study was our direct, unbiased and independent comparison of 5 published prediction scores. We only included patients with a short duration from the onset of AIS symptoms ensuring that the occurrence of SAP was a direct consequence of the AIS and not due to other inciting factors, such as prehospital delay for example. We ensured that the diagnosis of SAP for every patient was in accordance to the objective modified criteria established by CDC and recommended by PISCES[28] rather than via documentation of the diagnosis pneumonia in the medical notes. This reduced ambiguity of the diagnosis of SAP, which has been a subject of criticism.[4] We also attempted to reduce biases during our data collection by ensuring that the determination of the status of pneumonia was independent from the retrieval of the clinical predictors.

Conclusion

In summary, our study demonstrated that A^2DS^2, AIS-APS and Kwon's score had comparable discrimination capacity for SAP using the new operational definition in

AIS patients. These scores performed well in excluding AIS patients who are unlikely to develop SAP, hence using these scores may improve patient selection for future pneumonia prevention trials.

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