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# Risk Factors for Chest Infection in Acute Stroke

## A Prospective Cohort Study

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**Background and Purpose**—Pneumonia is a major cause of morbidity and mortality after stroke. We aimed to determine key characteristics that would allow prediction of those patients who are at highest risk for poststroke pneumonia.

**Methods**—We studied a series of consecutive patients with acute stroke who were admitted to hospital. Detailed evaluation included the modified National Institutes of Health Stroke Scale; the Abbreviated Mental Test; and measures of swallow, respiratory, and oral health status. Pneumonia was diagnosed by set criteria. Patients were followed up at 3 months after stroke.

**Results**—We studied 412 patients, 391 (94.9%) with ischemic stroke and 21 (5.1%) with hemorrhagic stroke; 78 (18.9%) met the study criteria for pneumonia. Subjects who developed pneumonia were older (mean  $\pm$  SD age,  $75.9 \pm 11.4$  vs  $64.9 \pm 13.9$  years), had higher modified National Institutes of Health Stroke Scale scores, a history of chronic obstructive pulmonary disease, lower Abbreviated Mental Test scores, and a higher oral cavity score, and a greater proportion tested positive for bacterial cultures from oral swabs. In binary logistic-regression analysis, independent predictors ( $P < 0.05$ ) of pneumonia were age  $> 65$  years, dysarthria or no speech due to aphasia, a modified Rankin Scale score  $\geq 4$ , an Abbreviated Mental Test score  $< 8$ , and failure on the water swallow test. The presence of 2 or more of these risk factors carried 90.9% sensitivity and 75.6% specificity for the development of pneumonia.

**Conclusions**—Pneumonia after stroke is associated with older age, dysarthria/no speech due to aphasia, severity of poststroke disability, cognitive impairment, and an abnormal water swallow test result. Simple assessment of these variables could be used to identify patients at high risk of developing pneumonia after stroke. (*Stroke*. 2007;38:2284-2291.)

**Key Words:** dysphagia ■ oral health ■ pneumonia ■ risk factors ■ stroke, acute

Chest infection is a common complication of acute stroke, affecting up to one third of patients.<sup>1-8</sup> Chest infection carries an  $\approx 3$ -fold increase in risk of death<sup>1,9</sup> and has the highest attributable mortality of all medical complications after stroke.<sup>10</sup> Chest infection is also associated with a greater likelihood of discharge to a nursing home<sup>11</sup> and increased length of hospital stay.<sup>4,5,11</sup>

Previous studies have identified a diverse set of factors that may predispose an individual to chest infection early in the course of stroke. These include greater severity of neurologic impairment,<sup>1,2,5,11,12</sup> older age,<sup>1,5</sup> and diabetes mellitus.<sup>1</sup> An unsafe swallow also may be an important contributor, with dysphagia or failed initial swallow evaluation associated with an increased risk of chest infection after stroke.<sup>8,13</sup> Additionally, many other risk factors for chest infection have been identified in studies of nonacute stroke patients and elderly populations, including oral health and the presence of oral pathogens.<sup>4,14-16</sup> Langmore and colleagues<sup>16</sup> have posited a staged model for aspiration pneumonia. This includes dependence for oral care, contributing to altered oral flora. This in turn is increased in concentration in the saliva, which has been reduced in volume

by the action of (multiple) medications. It constitutes a possible mechanism whereby bacterial colonization is aspirated into the lungs.

However, studies reporting on the possible predictors of chest infection after stroke have had limitations, such as the inclusion of nonstroke patients,<sup>16</sup> mixed acute and nonacute stroke populations,<sup>13,14,16</sup> nonblinded ascertainment of chest infection as part of an analysis of a stroke database or register,<sup>1,2,4,9,10</sup> retrospective analysis,<sup>14</sup> or reporting of secondary findings in a study with different primary aims.<sup>1,5,7,8</sup> Studies have also been restricted in the number of factors under consideration.<sup>2,4,15</sup>

In this study, we performed a comprehensive series of patient assessments (including measures of stroke severity, swallowing problems, respiratory status, and oral health) aiming to identify independent risk factors for chest infection after acute stroke.

## Subjects and Methods

### Subjects

We carried out a prospective cohort study of consecutive admissions to the Glasgow Royal Infirmary during a 17-month period (June

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2004 to November 2005). We included patients with first or recurrent ischemic or hemorrhagic stroke within 7 days of admission to hospital. We excluded patients at >7 days after admission and those who, after further investigation, had a diagnosis other than stroke. The diagnosis of stroke was based on clinical features supported by brain computed tomography or magnetic resonance imaging scanning. Permission to participate was sought from all patients or their caregivers, and the study had the approval of the Multicenter Research Ethics Committee for Scotland.

## Procedures

A research speech and language therapist with training and experience in the field of stroke and dysphagia identified and verified the patients and documented standard demographic information, including premorbid functioning, details of prior medical history, medications on admission, and baseline characteristics. Further documentation included the Oxfordshire Community Stroke Project (OCSP) clinical classification,<sup>12</sup> modified National Institutes of Health Stroke Scale (mNIHSS),<sup>17</sup> modified Rankin Scale (mRS),<sup>18</sup> Barthel Activities of Daily Living Index,<sup>19</sup> Abbreviated Mental Test (AMT),<sup>20</sup> and nutritional status.<sup>21</sup>

The condition of the oral cavity was assessed with the Oral Assessment Guide.<sup>22</sup> The presence of oral yeasts, coliforms, and *Staphylococcus aureus* was determined by imprint culture, and salivary flow rates were measured by Salivette (Sarstedt Ltd, Leicester, UK) sampling, as described by Sweeney et al.<sup>23</sup> For the imprint culture, a sterile foam pad (1×1 cm) was applied to the sample site for 5 seconds. The pad was then used to sequentially inoculate individual plates of Sabouraud's agar and Pagano Levin agar for yeast culture, mannitol salt agar for *Staphylococcus aureus*, and MacConkey agar for coliforms. The plates were transported to the laboratory within 3 hours for incubation and processed according to standard methods. To determine salivary flow rates, the insert from a sterile Salivette was placed beneath the tongue for 30 seconds. It was then removed and replaced in the inner tube of the Salivette, and the unit was sealed. On arrival at the laboratory, the Salivette was centrifuged at 4000 rpm in a bench-top centrifuge (Centaur 1, Fisons, Crawley, Sussex, UK), and the volume of saliva that collected in the outer tube was measured by means of a microsyringe.

The presence and severity of dysphagia were determined by a staged water swallow test (WST)<sup>24</sup> involving progressively larger amounts of water: 3×5-mL teaspoons, 10 mL, 20 mL, and then 50 mL of water from a cup, with the procedure being discontinued at any stage if there was evidence of coughing, choking, voice change, or (increased) breathlessness. Detailed clinical assessment of swallowing was a composite of protocols validated against videofluoroscopy of swallow.<sup>25,26</sup> Routine pulse oximetry data at the time of admission were recorded. We further characterized oxygen saturation (SpO<sub>2</sub>) by pulse oximetry (Pulsox 3iA, Konica Minolta) at the time of the clinical swallow evaluation according to a protocol similar to that of Rowat and colleagues.<sup>27</sup>

The presence of in-hospital chest infection was determined by scrutiny of the medical case records by an independent medical assessor using standardized criteria (Mann criteria pneumonia).<sup>8</sup> Specifically, subjects were required to have 3 or more of the following characteristics: fever (>38°C), productive cough with purulent sputum, abnormal respiratory examination (tachypnea >22/min, tachycardia, inspiratory crackle, bronchial breathing), abnormal chest radiographic findings, arterial hypoxemia (Po<sub>2</sub> <70 mm Hg or SpO<sub>2</sub> <94%), and isolation of a relevant pathogen (positive Gram's stain and culture). Suspected pneumonia was recorded when patients did not fulfill the standard Mann criteria but had been diagnosed by the attending physicians (in hospital) or general practitioner (after discharge). The research speech and language therapist and assessors of pneumonia were blinded to each other's findings. Participants were also followed up at 3 months after stroke to determine survival and/or development of chest infection after discharge from the hospital.

## Data Analysis and Statistical Methods

Our power calculations were based on pilot data from our service, which had shown that an abnormal WST had 75% accuracy for predicting patients' receiving early antibiotic therapy (taken as a surrogate to indicate the presence of any infection). To demonstrate (with 80% power at 5% significance) an improved prediction to 85% would require 500 patients.

Data were analyzed with the Statistical Package for the Social Sciences software (version 14.0). The characteristics of those patients with Mann criteria pneumonia were compared with those with no pneumonia (results for suspected pneumonia not fulfilling the Mann criteria were also summarized but not included in the full primary analysis). Summary statistics included sensitivity, specificity, and odds ratios (ORs) for baseline characteristics or observations and the risk of developing Mann criteria pneumonia. Statistical comparisons were made for Mann criteria pneumonia versus no pneumonia. For normally distributed continuous variables (described as mean and SD), analysis was made by unpaired Student's *t* test. For nonnormally distributed continuous variables, analysis was made by the Mann-Whitney *U* test. Categorical variables were analyzed by the  $\chi^2$  test. All probabilities are 2-tailed. Statistical significance was accepted at *P*=0.05. Results are expressed as mean (and SD), median (and interquartile range [IQR]), or number (and percentage).

Binary logistic-regression analysis (forward logistic regression) was performed with the dependent variable (Mann criteria) pneumonia or no pneumonia; further secondary analysis of suspected pneumonia was also undertaken. This analysis was used to select key risk variables, which then were used to explore the optimal cutoff in terms of the number of risk factors in the prediction of pneumonia; a summary receiver operating characteristic curve was calculated for combinations of key risk variables, with sensitivities and specificities for pneumonia for increasing numbers of risk factors.

## Results

Of 938 patients with suspected stroke identified during the study recruitment period, 643 were confirmed stroke patients, and 412 of them were recruited into and remained in the study (Figure 1). Reasons for exclusion included diagnosis other than stroke, late referral, and researcher leave. Patients were assessed at a median of 5 days (IQR, 2 to 6 days) after stroke. In total, 78 of 412 (18.9%) patients fulfilled the Mann criteria for pneumonia, 82 (19.9%) were diagnosed as having pneumonia by the attending clinicians but did not fulfill the Mann criteria (suspected pneumonia), 236 (57.3%) had no pneumonia, and 8 were lost to follow-up for pneumonia assessment. There was a total of 66 deaths in the study, 33 of 78 (42.3%) in patients with Mann criteria pneumonia, 21 of 81 (25.9%) in the suspected pneumonia group, and 8 of 236 (3.3%) in the no pneumonia group (4 deaths were in patients lost to follow-up), giving a  $\chi^2$  statistic of 77.6 (*P*<0.001). The full range of observations and assessments was undertaken in 365 of 412 (88.6%) patients.

The study population had a mean age of 67 years (range, 30 to 98 years) with almost half the patients being male. The major diagnosis was cerebral infarction (n=391, 94.9%) with the remainder being primary intracerebral hemorrhage (n=21, 5.1%). There was a wide range of stroke severity, with 80 (19.4%) classified as total anterior circulation syndrome.<sup>12</sup>

## Oral Health

Only 132 (32%) patients had their own dentition. On testing for xerostomia, we found that more than half the patients had no detectable salivary flow. Salivary flow rate was correlated

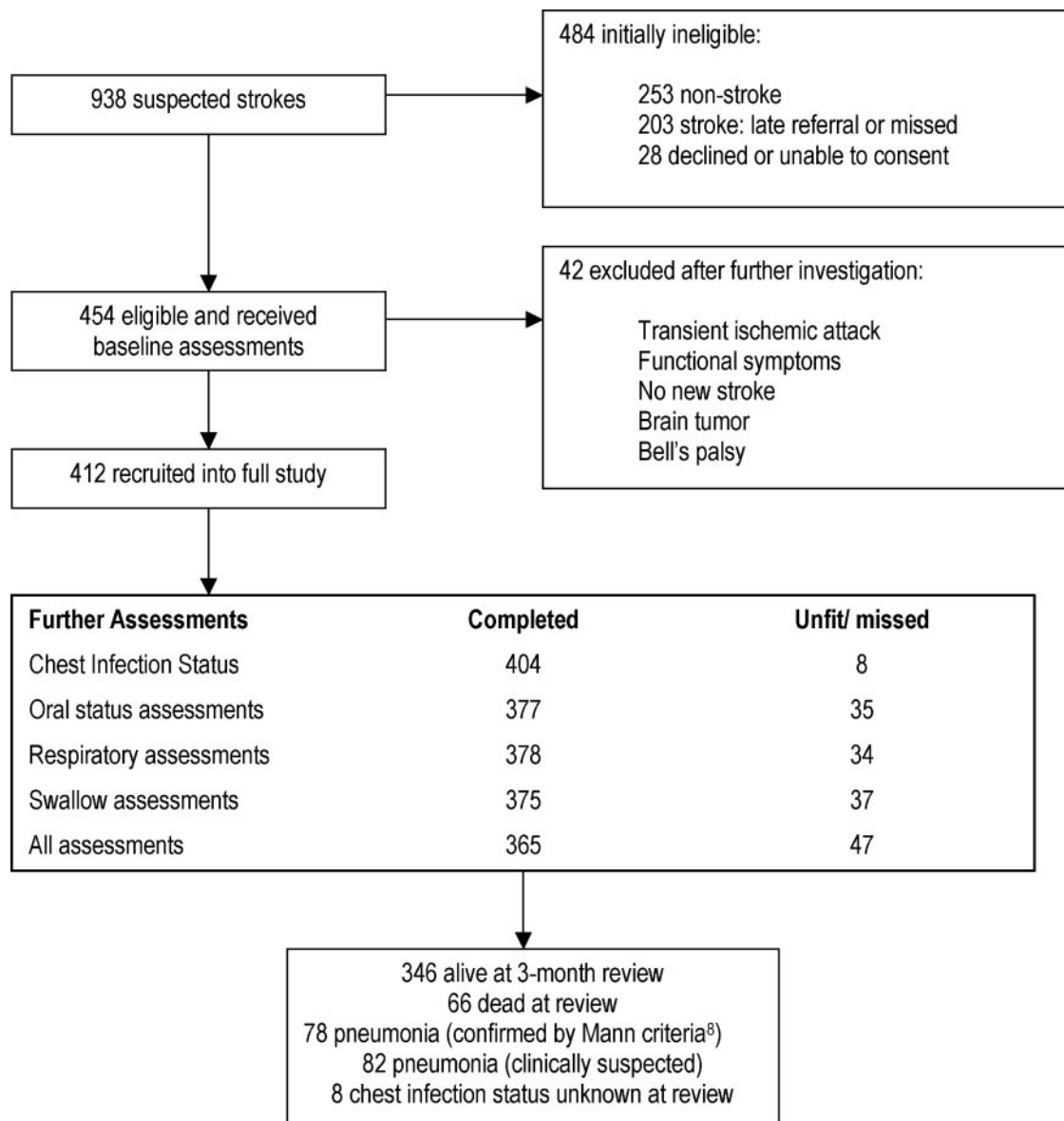


Figure 1. Flowchart of patient recruitment and study requirement outcomes.

inversely with admission blood urea (Spearman  $r = -0.113$ ,  $P = 0.03$ ,  $n = 368$ ) and mNIHSS score ( $r = -0.147$ ,  $P = 0.005$ ,  $n = 366$ ) but was not significantly correlated with clinical predictors of dysphagia.<sup>25,26</sup> Coliforms, *Staphylococcus aureus*, or both were cultured from nearly a quarter of all patients ( $n = 94$ , 22.8%); of these, the biggest proportion was strains of *Staphylococcus aureus* ( $n = 54$ , 13.1% of the total population).

### Swallow Status

In our cohort, 112 (27.2%) failed an initial WST. More detailed clinical testing of swallow function according to the protocols of Daniels et al<sup>25</sup> and Logemann et al<sup>26</sup> suggested that 127 patients (30.8%) had an oral-stage swallowing disorder, 74 (18%) had delay in initiation of the pharyngeal swallow, 49 (11.9%) had a pharyngeal-stage swallowing disorder, 74 (18%) were observed to aspirate, and 101 (24.5%) had dysphagia of moderate or greater severity. In the course of hospital admission, 44 (10.7%) were tube-fed (nasogastric or gastrostomy).

### Respiratory Status

A previous history of chronic obstructive pulmonary disease (COPD) was reported in 42 (10.2%) patients. During the detailed swallow assessment, 85 (20.6%) individuals experienced a drop in  $SpO_2$  of  $>4\%$ ; the reduction in  $SpO_2$  was seen at baseline (before the swallow test) in 45 patients (10.9% of the total population), during the swallow evaluation in 13 (3.2%), and after evaluation in 27 (6.6%).

### Data Analysis

The characteristics of those patients with Mann criteria or suspected pneumonia were compared with those with no pneumonia in a univariate statistical analysis (Table 1). Table 2 gives details of the sensitivity and specificity of the 10 most discriminating variables and provides ORs for developing Mann criteria pneumonia. These range from 3.5 (COPD) to 20.1 (failed or unable to undertake a WST).

We further analyzed the data by binary logistic-regression analysis (forward logistic regression; Table 3). The dependent

**TABLE 1. Univariate Analysis of Patient Demographics, Prior Clinical Characteristics, and Clinical Findings and Basic Investigations on Admission and Oral, Swallowing, and Respiratory Assessments**

	All Patients	No Pneumonia	Suspected Clinical Pneumonia	Pneumonia (Mann Criteria)	P (Mann Criteria Pneumonia vs No Pneumonia)
No.	412	244 (59.2%)	82 (19.9%)	78 (18.9%)	...
Age, mean (SD), y	67.9 (13.9)	64.9 (13.9)	68.4 (13.0)	75.9 (11.4)	P<0.001
Sex, male:female	205:207	124:120	32:50	45:33	NS
No. of medications, mean (SD)	5.7 (3.9)	5.3 (3.8)	6.0 (4.2)	6.5 (3.9)	NS
Current smoker	192/412 (46.6%)	121/244 (49.6%)	46/82 (56.1%)	22/78 (28.2%)	P<0.001
Prestroke mRS score, <sup>18</sup> median (IQR)	0 (0, 1) n=367	0 (0, 0), n=230	0 (0,1), n=72	0 (0, 2), n=58	P<0.011
Prestroke Barthel Index, <sup>19</sup> median (IQR)	20 (18, 20) n=358	20 (20, 20), n=226	20 (18, 20), n=66	20 (17, 20), n=58	P<0.001
Previous stroke	168/412 (40.8%)	93/244 (38.1%)	41/82 (50.0%)	28/78 (35.9%)	NS
Ischemic heart disease	146/412 (35.4%)	89/244 (36.5%)	26/82 (31.7%)	29/78 (37.2%)	NS
Peripheral vascular disease	20/412 (4.9%)	13/244 (5.3%)	5/82 (6.1%)	2/78 (2.6%)	NS
COPD	42/412 (10.2%)	13/244 (5.3%)	15/82 (18.3%)	13/78 (16.7%)	P=0.001
Congestive heart failure	38/412 (9.2%)	24/244 (9.8%)	6/82 (7.3%)	8/78 (10.3%)	NS
Diabetes mellitus	70/412 (17.0%)	36/244 (14.8%)	16/82 (19.5%)	16/78 (20.5%)	NS
Hypertension	227/412 (55.1%)	139/244 (57.0%)	28/82 (58.5%)	37/78 (47.4%)	NS
Gastroesophageal reflux or peptic ulcer disease	28/412 (6.8%)	19/244 (7.8%)	4/82 (4.9%)	5/78 (6.4%)	NS
Infarct:hemorrhage	391:21	232:12	75:7	76:2	NS
OCSPI <sup>2</sup> total anterior circulation syndrome	80/402 (19.9%)	27/237 (11.4%)	17/79 (21.5%)	31/78 (39.7%)	P<0.001
Heart rate, beats per minute	83.5 (21.0), n=406	80.2 (20.0), n=240	84.7 (20.5), n=80	92.4 (22.5), n=78	P<0.001
Respiratory rate, breaths per minute	17.4 (3.2), n=401	16.9 (2.5), n=236	17.9 (3.6), n=80	18.5 (4.4), n=77	P=0.004
SpO <sub>2</sub> , %	96.8 (2.8), n=410	97.2, n=243	96.9 (2.4), n=82	96.0 (3.8), n=77	P=0.01
Serum urea, mmol/L	6.7 (3.2), n=412	6.1 (2.8), n=244	6.9 (4.0), n=82	7.7 (3.2), n=82	P<0.001
Serum albumin, g/L	40.1 (5.7), n=407	40.8 (5.1), n=241	41.1 (7.0), n=80	37.0 (5.2), n=78	P<0.001
Nutritional status <sup>21</sup> : undernourished	65/412 (15.8%)	28/244 (11.5%)	15/82 (18.3%)	20/78 (25.6%)	P=0.002
mNIHSS <sup>17</sup> score, median (IQR)	5 (2, 11), n=409	4 (2, 6), n=243	5 (2, 11.5), n=81	14 (9, 17), n=77	P<0.001
mRS <sup>18</sup> score, median (IQR)	3 (2, 4), n=412	3 (2, 4), n=244	3 (2, 4), n=82	5 (4, 5), n=78	P<0.001
AMT <sup>20</sup> score, median (IQR)	8 (2, 9.5), n=406	9 (7, 10), n=240	8 (0, 9), n=81	3 (0, 6), n=77	P<0.001
Dentures	211/402 (52.5%)	139/240 (57.9%)	36/81 (44.4%)	35/73 (47.9%)	NS
No teeth or dentures	59/402 (14.7%)	17/240 (7.1%)	18/81 (22.2%)	22/73 (30.1%)	P<0.001
Oral health status <sup>22</sup> score, median (IQR)	10 (8, 13), n=388	9 (8, 11), n=239	11 (8, 14), n=77	14 (11, 18), n=52	P<0.001
Salivary flow rate, μL/min	0 (0, 100), n=368	0 (0, 100), n=236	0 (0, 100), n=73	0 (0, 100), n=52	NS
Oral Gram-positive bacteria	55/377 (14.6%)	28/238 (11.8%)	11/75 (14.7%)	15/57 (26.3%)	P=0.005
Oral Gram-negative bacteria	48/377 (12.7%)	26/238 (10.9%)	8/75 (10.7%)	12/57 (21.1%)	P=0.04
Failed WST	112/412 (27.2%)	26/244 (10.7%)	28/82 (34.1%)	55/78 (70.5%)	P<0.001
Logemann et al <sup>26</sup> total score, median (IQR)	1 (0, 5), n=375	0.5 (0, 2), n=236	2 (0, 8), n=76	9 (4, 16.5), n=57	P<0.001
Logemann et al <sup>26</sup> oral-stage disorder	127/375 (33.9%)	54/236 (22.9%)	28/76 (36.8%)	43/57 (75.4%)	P<0.001
Logemann et al <sup>26</sup> pharyngeal delay	74/375 (19.7%)	20/236 (8.5%)	22/76 (28.9%)	31/57 (54.4%)	P<0.001
Logemann et al <sup>26</sup> pharyngeal-stage disorder	49/375 (13.1%)	13/236 (5.5%)	15/76 (19.7%)	20/57 (35.1%)	P<0.001
Logemann et al <sup>26</sup> aspiration	74/375 (19.7%)	28/236 (11.9%)	17/76 (22.4%)	28/57 (49.1%)	P<0.001
Daniels et al <sup>25</sup> severity of dysphagia	0 (0, 2), n=375	0 (0, 1), n=236	0 (0, 2), n=76	3 (1, 4), n=57	P<0.001
Mean SpO <sub>2</sub> during swallow assessment, %	95.8 (2.1), n=378	96.2 (1.5), n=237	95.8 (1.8), n=74	94.1 (3.5), n=61	P<0.001
Lowest SpO <sub>2</sub> during swallow assessment, %	92.4 (4.2), n=375	93.1 (3.2), n=237	93.2 (3.6), n=74	89.1 (5.7), n=58	P<0.001

The Barthel Index is a 20-point scale. NS indicates not significant.

**TABLE 2. Predictors of (Mann Criteria) Pneumonia<sup>a</sup> and Sensitivity, Specificity, and ORs of Individual Binary Variables**

	Sensitivity	Specificity	Mantel-Haenszel Common OR (95% CI)
Age $\geq 65$ years	65/78 (83.3%)	65/202 (32.2%)	3.9 (2.0, 7.5)
COPD	13/78 (16.7%)	13/26 (50%)	3.5 (1.6, 8.0)
mNIHSS <sup>17</sup> score $>6$	63/78 (80.8%)	63/123 (51.2%)	12.9 (6.8, 24.2)
mRS <sup>18</sup> score $\geq 4$	68/78 (87.2%)	68/145 (46.9%)	14.7 (7.2, 30.2)
OCSF total anterior circulation syndrome <sup>12</sup>	31/78 (39.7%)	31/58 (53.4%)	5.3 (2.9, 9.7)
AMT <sup>20</sup> score $<8/10$	66/78 (84.6%)	66/143 (46.2%)	11.7 (6.0, 22.9)
Logemann et al <sup>26</sup> $\geq 2/28$	72/78 (92.3%)	72/164 (43.9%)	19.8 (8.3, 47.4)
Dysarthria/no speech <sup>26</sup>	68/78 (82.1%)	64/126 (50.8%)	13.4 (7.0, 25.6)
Failed WST	55/78 (70.5%)	55/81 (67.9%)	20.1 (10.6, 37.8)
Oral health status <sup>22</sup> $>10/24$	52/78 (66.7%)	52/134 (38.8%)	3.9 (2.3, 6.8)

variable was Mann criteria pneumonia/no pneumonia; independent binary variables were age ( $>65$  years), COPD, mNIHSS score  $>6$ , mRS score  $\geq 4$ , total anterior circulation syndrome, AMT score  $<8/10$ , Logemann swallow assess-

ment score  $>2$ , Daniels swallow assessment score  $>1$ , Oral Assessment Guide score  $>10$ , WST unsafe or unable, dysarthria or no speech due to aphasia,<sup>26</sup> and blood urea value  $>8$  mmol/L. Model 5, including age  $>65$  years, dysarthria or

**TABLE 3. Independent Predictors of Pneumonia After Acute Stroke**

	Variables in the Equation			df	Significance	Exp (B)
	B	SE	Wald			
Step 1(a)						
Failed WST	2.984	0.324	85.008	1	0.000	19.774
Constant	-2.235	0.219	103.801	1	0.000	0.107
Step 2(b)						
AMT $<8$	1.783	0.378	22.192	1	0.000	5.946
Failed WST	2.457	0.344	51.072	1	0.000	11.666
Constant	-3.111	0.338	84.825	1	0.000	0.045
Step 3(c)						
Dysarthria/no speech	1.418	0.412	11.866	1	0.001	4.130
AMT $<8$	1.724	0.387	19.853	1	0.000	5.608
Failed WST	1.686	0.400	17.753	1	0.000	5.398
Constant	-3.559	0.390	83.229	1	0.000	0.028
Step 4(d)						
Age $\geq 65$	1.190	0.419	8.069	1	0.005	3.288
Dysarthria/no speech	1.478	0.416	12.637	1	0.000	4.383
AMT $<8$	1.612	0.394	16.769	1	0.000	5.015
Failed WST	1.669	0.405	16.989	1	0.000	5.308
Constant	-4.372	0.523	69.816	1	0.000	0.013
Step 5(e)						
Age $\geq 65$	1.197	0.424	7.952	1	0.005	3.310
Dysarthria/no speech	1.315	0.431	9.310	1	0.002	3.724
mRS $\geq 4$	1.069	0.459	5.435	1	0.020	2.913
AMT $<8$	1.442	0.405	12.697	1	0.000	4.229
Failed WST	1.288	0.437	8.677	1	0.003	3.625
Constant	-4.722	0.573	67.956	1	0.000	0.009

Binary logistic-regression analysis (forward logistic regression) was performed with the dependent variable Mann criteria pneumonia<sup>a</sup>/no pneumonia; independent binary variables were age  $\geq 65$  years, COPD, mNIHSS<sup>17</sup> score  $>6$ , mRS<sup>18</sup> score  $\geq 4$ , OCSF<sup>12</sup> total anterior cerebral syndrome, AMT<sup>20</sup> score  $<8/10$ , Logemann et al<sup>26</sup> score  $\geq 2$ , Daniels et al<sup>25</sup> score  $\geq 1$ , Oral Assessment Guide<sup>22</sup> score  $>10$ , WST unsafe or unable, dysarthria or no speech,<sup>26</sup> and blood urea  $\geq 8$  mmol/L.

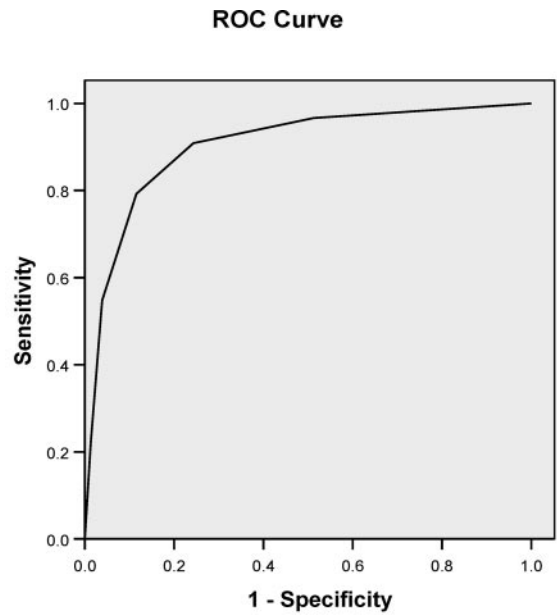
no speech due to aphasia, mRS score  $\geq 4$ , AMT  $< 8$ , and failed WST, correctly predicted 59 of 78 (75.6%) cases of pneumonia and 219 of 241 (90.9%) cases of nonpneumonia. Further analysis of these 5 independent predictors showed that subjects with 2 or more risk factors had a 75.6% chance of developing pneumonia (specificity). Of those who developed pneumonia, 90.9% had 2 or more predictors (sensitivity). This is graphically represented in a receiver operating characteristic curve (Figure 2). We performed a secondary analysis by binary logistic regression as described but used suspected pneumonia (not fulfilling Mann criteria)/no pneumonia as the dependent variable; COPD (exponential coefficient (B) OR=4.13,  $P=0.001$ ) and failing the WST (OR=4.46,  $P<0.001$ ) were independent predictors of suspected pneumonia.

**Discussion**

In this study, we explored a comprehensive range of features implicated in the development of chest infection. We included demographic, clinical, and neurologic factors as well as detailed assessments of swallowing function, oral health, and oral microbiology. Our findings confirm the multifactorial nature of chest infection in acute and postacute stroke but also indicate that a few relatively simple clinical characteristics may provide the most robust predictors. Of the 10 factors that were independently associated with an increased risk of developing Mann criteria pneumonia, 5 (age  $> 65$  years, dysarthria or no speech due to aphasia, mRS score  $\geq 4$ , AMT score  $< 8$ , and failed WST) were useful predictors. Two or more of these factors predicted Mann criteria pneumonia in our population with a sensitivity of 90.9% and a specificity of 75.6%. There was a large number of suspected pneumonia cases observed in this study that were diagnosed by the attending physicians but did not meet all of the Mann criteria for pneumonia, which formed our primary preplanned analysis. These suspected pneumonia cases were generally associated with a health status between that of the Mann criteria pneumonia and no pneumonia groups, with less severe neurologic impairment and fewer swallowing problems than in Mann pneumonia cases. This group with suspected pneumonia included patients in whom the diagnosis of pneumonia was not certain, and therefore they did not form part of our primary analysis.

Our univariate analyses highlighted the potential contribution of a number of factors already identified by others: clinical stroke severity (OCSP total anterior circulation syndrome),<sup>1</sup> initial NIHSS score,<sup>1,5</sup> and lower serum albumin level.<sup>2</sup> Of our 5 independent predictors, 2 have been reported elsewhere in the acute stroke literature, namely, older age<sup>1,5</sup> and dysphagia or failure on the initial swallow evaluation.<sup>8,13</sup>

In a wider context of predictors for chest infection in nonacute stroke and elderly populations, we note some agreement in terms of the associations with COPD,<sup>14,16</sup> current smoking,<sup>16</sup> level of dependence,<sup>16</sup> oral health status,<sup>16</sup> and presence of bacterial pathogens in the mouth.<sup>4,15</sup> However, we have not found independent associations with gastrointestinal disease,<sup>16</sup> number of medications or dry mouth,<sup>16</sup> and multiple strokes.<sup>14</sup>



Diagonal segments are produced by ties.

Area under ROC curve = 0.903 (S.E. 0.020, 95% CI 0.864,0.943).

**Coordinates of the Curve**

Test Result Variable(s): number of predictors of pneumonia

Positive if Greater Than or Equal To(a)	Sensitivity	1 - Specificity
0	1.000	1.000
1	.967	.513
2	.909	.244
3	.793	.115
4	.548	.038
5	.220	.013

**Figure 2.** Receiver operating characteristic curve calculated for summary risk variables for Mann criteria pneumonia,<sup>8</sup> combining age  $\geq 65$  years, dysarthria or no speech due to aphasia,<sup>26</sup> mRS<sup>18</sup> score  $\geq 4$ , AMT score<sup>20</sup>  $< 8$ , and failed WST, with a score of 1 given for each of the above, for a maximum total risk score of 5.

Langmore and colleagues<sup>16</sup> sought to develop a 3-stage model of causation to explain their findings for aspiration pneumonia in a population that included but was not exclusively composed of stroke patients. They postulated that colonization of oral flora, aspiration, and host resistance, stages supported by their independent predictors, as a likely chain of cause and effect. Our findings offer some support to the model of Langmore et al, but we were unable to confirm suspicions that dry mouth (whether resulting from polypharmacy or otherwise) is a key mechanism in the development of pneumonia. Our 5 key factors are compatible with this model and have considerable plausibility in their own right. We found evidence that greater disability may be an important factor<sup>18</sup>: more

disabling strokes are likely to be associated with a propensity to aspiration and hypostatic pneumonia.<sup>1,5</sup> Dysphagia is a necessary but not sufficient condition for pneumonia to develop<sup>8,13,16</sup> and was clearly shown to be important in our study by a number of validated measures.<sup>24–26</sup> It is plausible that its effect is enhanced by confusion, a factor demonstrated in this study by an AMT score <8.

The current study has a number of strengths. We believe it to be the first prospective cohort study of an acute stroke population with the specific aim of identifying risk factors for chest infection. It aimed to be comprehensive in its scope and included both ischemic and hemorrhagic stroke, providing ongoing data by means of follow-up to 3 months. The assessments of chest infection status were blinded to other patient characteristics. However, there are also some potential weaknesses. We did not distinguish between infections that had a community rather than a hospital origin.<sup>4</sup> Our data for determining chest infection in patients after discharge from the hospital were based on a telephone inquiry and questionnaire and are not as robust as those gathered in hospital according to well-recognized criteria.<sup>8</sup> Also, we were unable to undertake an instrumental investigation of swallowing impairments, such as videofluoroscopy of swallow.<sup>8</sup> In response to these possible criticisms, we point out that our study was designed to be as clinically relevant as possible, focusing on data that are routinely available or could be quickly determined by simple testing. In a practical clinical setting, it is unlikely to be necessary to distinguish between community-acquired and hospital-acquired pneumonia. We do not view the lack of instrumental evaluation of swallowing as a major drawback, as we set out to use well-researched swallow protocols validated against videofluoroscopy of swallow.<sup>25,26</sup>

Our findings are important in that we were able to confirm several predictive factors reported in previous studies. It is likely that some of the variation in findings among different studies can be attributed to differences in study design. In addition, we studied a cohort from a region with high rates of socioeconomic deprivation; this is consistent with features such as the low rate of intact dentition. Further testing in other cohorts may assist in refining the relative importance of the key factors in our study and in further validating our findings. This could in turn lead to the development of a robust early screening tool that could form the basis for supporting intervention studies in the management of chest infection risk in acute stroke.

Regardless of future research initiatives, our 5 key factors constitute the basis of a simple screening tool that could be readily put into clinical practice by nursing and medical staff seeking to identify on admission the patient at greater risk of developing a chest infection. It could also provide a baseline for testing interventions thought to reduce pneumonia risk, including early mobilization,<sup>28</sup> swallowing therapy, alternative feeding methods to reduce the impact of dysphagia,<sup>29,30</sup> and early antibacterial treatment for oral pathogens.<sup>15</sup>

## Conclusions

We found that pneumonia after stroke is independently associated with older age, speech loss, severity of poststroke disability, cognitive impairment, and an abnormal WST result. These observations require confirmation in other stroke cohorts but could form the basis for identifying patients at high risk of this common poststroke complication.

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## Disclosures

None.

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