Arterial Blood Gas and Pulse Oximetry in Initial Management of Patients with Community-acquired Pneumonia

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OBJECTIVE: **To identify the factors associated with the use of arterial blood gas (ABG) and pulse oximetry (PO) in the initial management of patients with community-acquired pneumonia (CAP) and arterial hypoxemia at presentation.**

PARTICIPANTS: **A total of 944 outpatients and 1,332 inpatients with clinical and radiographic evidence of CAP prospectively enrolled from 5 study sites in the United States and Canada.**

ANALYSES: **Separate multivariate logistic regression analyses were used to 1) compare measurement of ABG and PO within 48 hours of presentation across sites while controlling for patient differences, and 2) identify factors associated with arterial hypoxemia (PaO_2 <60 mm Hg or SaO_2 <90% for non–African Americans and <92% for African Americans) while breathing room air.**

RESULTS: **Range of ABG use by site was from 0% to 6.4% ($P = .06$) for outpatients and from 49.2% to 77.3% for inpatients ($P < .001$), while PO use ranged from 9.4% to 57.8% for outpatients ($P < .001$) and from 47.9% to 85.1% for inpatients ($P < .001$). Differences among sites remained after controlling for patient demographic characteristics, comorbidity, and illness severity. In patients with 1 or more measurements of oxygenation at presentation, hypoxemia was independently associated with 6 risk factors: age >30 years (odds ratio [OR], 3.2; 95% confidence interval [CI], 1.7 to 5.9), chronic obstructive pulmonary disease (OR, 1.9; 95% CI, 1.4 to 2.6), congestive heart failure (OR, 1.5; 95% CI, 1.0 to 2.1), respiratory rate >24 per minute (OR, 2.3; 95% CI, 1.8 to 3.0), altered mental status (OR, 1.6; 95% CI, 1.1 to 2.3), and chest radiographic infiltrate involving >1 lobe (OR, 2.2; 95% CI, 1.7 to 2.9). The prevalence of hypoxemia among those tested ranged from 13% for inpatients with no risk factors to 54.6% for inpatients with ≥3 risk factors. Of the 210 outpatients who had ≥2 of these risk factors, only 64 (30.5%) had either an ABG or PO performed. In the 48 outpatients tested without supplemental O_2 with ≥2 risk factors 8.3% were hypoxemic.**

CONCLUSIONS: **In the initial management of CAP, use of ABG and PO varied widely across sites. Increasing the assessment of arterial oxygenation among patients with CAP is likely to increase the detection of arterial hypoxemia, particularly among outpatients.**

KEY WORDS: **community-acquired pneumonia; hypoxemia; blood gas analysis; oximetry.**
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Measurement of arterial oxygenation is important in the initial evaluation of patients with community-acquired pneumonia (CAP). Hypoxemia has been associated with impending respiratory failure, subsequent intensive care unit admission,[1] and mortality[2,3] in patients with CAP, reflecting the severity of primary organ impairment in this illness. Furthermore, the identification of arterial hypoxemia has direct treatment implications, including the delivery of supplemental oxygen and hospitalization for more intensive clinical observation. Hypoxemia has also been rated "very important" by physicians in the hospitalization decision for patients with CAP.[4] For these reasons, measurement of arterial oxygenation has been identified as an important quality indicator in the initial management of patients with CAP.[5,6]

Meehan et al. documented wide variation in the assessment of arterial oxygenation in Medicare inpatients with CAP.[7] However, that study dealt exclusively with an elderly inpatient population, did not differentiate pulse oximetry (PO) from arterial blood gas (ABG) measurements, and did not assess the factors associated with the variation in testing across treatment sites or with the detection of arterial hypoxemia.

The goals of this study were to: 1) describe the use of ABG and PO in the initial evaluation of outpatients and inpatients with CAP across study sites; 2) identify the factors associated with obtaining these tests; 3) identify the baseline patient characteristics associated with arterial hypoxemia at presentation; and 4) assess the association between hypoxemia and clinical outcomes. To accomplish these goals, we analyzed data collected as part of the Pneumonia Patient Outcomes Research Team (PORT) cohort study, a multicenter, prospective, observational study that described the processes of care and medical outcomes for ambulatory and hospitalized patients with CAP.[1]

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METHODS

Study Sites

The Pneumonia PORT cohort study was conducted from October 1991 through March 1994 at 5 medical institutions: University of Pittsburgh Medical Center (UPMC), a 942-bed university teaching hospital, and St. Francis Medical Center (SFMC), a 427-bed community teaching hospital, in Pittsburgh, Pa; Massachusetts General Hospital (MGH), an 899-bed university teaching hospital; Harvard Community Health Plan–Kenmore Center (HCHP), a clinical site with 44,931 members within a staff-model health maintenance organization, in Boston, Mass; and Victoria General Hospital (VGH), a 637-bed university teaching hospital, in Halifax, Nova Scotia, Canada. This study was approved by the Biomedical Institutional Review Boards of each study site. None of the sites had explicit policies or protocols regarding ABG and PO use during the conduct of the study.

Patient Enrollment

Potential study subjects were identified by research assistants through daily reviews of admitting and radiology department logs and by records of patients presenting to emergency departments and medical walk-in clinics affiliated with the participating sites. To be included in this study of adults with CAP, patients had to be at least 18 years of age, have 1 or more acute clinical symptoms suggestive of pneumonia, have radiographic evidence of pneumonia within 24 hours of presentation, and provide informed consent for baseline and follow-up interviews. Patients were ineligible for the study if they had been discharged from an acute-care hospital within 10 days preceding the presentation for CAP, were known to be seropositive for the human immunodeficiency virus, had a definitive diagnosis other than pneumonia as the likely explanation for the pulmonary symptoms and infiltrate (e.g., lung carcinoma, pulmonary edema, or pulmonary embolus), or were previously enrolled in the study.

All 944 patients initially treated in an ambulatory setting, including those who were subsequently admitted to a hospital, were classified as outpatients. All 1,343 patients admitted to a hospital upon presentation were classified as inpatients. Both outpatients and inpatients were enrolled from each of the four hospital-based sites (UPMC, SFMC, MGH, and VGH); only outpatients were enrolled from HCHP. Eleven of the 1,343 inpatients enrolled in the Pneumonia PORT cohort study who were intubated or mechanically ventilated at the time of presentation were excluded from this assessment of ABG and PO use.

Baseline Patient Characteristics

Sociodemographic characteristics and clinical data were collected on all subjects by interviews of patient or proxy respondents and by review of medical records (Table 1). Clinical data collected included symptoms and physical examination findings at presentation, comorbid illnesses, and pertinent laboratory findings within 48 hours of presentation. The symptoms included in this analysis were the respiratory symptoms (cough, dyspnea, sputum production, pleuritic chest pain, and hemoptysis) and the 3 most common nonrespiratory symptoms (fatigue, fever, and sweats). The physical examination findings were vital signs (temperature, pulse, respiratory rate, and blood pressure) and altered mental status. Altered mental status was defined as disorientation to person, place, or time, or lethargy, stupor, coma, or confusion representing an acute change from a patient's usual state prior to presentation with pneumonia. The presence or absence of the following comorbid conditions was assessed: cigarette smoking, chronic obstructive pulmonary disease, asthma, restrictive

Table 1. Baseline Demographic and Clinical Characteristics

Characteristics	Outpatients (*N* = 944) *n*	Outpatients (*N* = 944) %*	Inpatients (*N* = 1,332) *n*	Inpatients (*N* = 1,332) %*
Demographic				
Age, y				
≤30	239	25.3	86	8.5
31–50	397	42.1	251	18.8
51–70	190	20.1	371	27.9
>70	118	12.5	624	46.8
Gender, male	441	46.7	697	52.3
Race, white	789	83.6	1152	86.5
Medical insurance				
Medicare or private insurance	474	50.2	811	61.2
Medicaid	50	5.3	113	8.5
Medical Services Insurance (Canada)	367	38.4	344	26.0
Uninsured	53	5.6	57	4.3
Health maintenance organization member	204	21.6	47	3.5
Selected cardiopulmonary conditions				
Current smoker	266	28.3	335	25.5
Coronary artery disease	57	6.0	349	26.2
Chronic obstructive pulmonary disease	51	5.4	349	26.2
Congestive heart failure	28	3.0	222	16.7
Asthma	78	8.3	115	8.6
Valvular heart disease	21	2.2	78	5.9
Restrictive lung disease	17	1.8	54	4.1
Any cardiopulmonary disease†	194	20.6	723	54.3
Severity of illness				
Risk class I	587	62.2	185	13.9
Risk class II	244	25.8	231	17.3
Risk class III	72	7.6	253	19.0
Risk class IV	40	4.2	443	33.3
Risk class V	1	.1	220	16.5

* *Missing data were excluded from the denominator; data were missing for <2% of patients for all variables for outpatients and inpatients.*

† *Any cardiopulmonary disease was defined as the presence of 1 or more of the following: chronic obstructive pulmonary diseases: asthma, restrictive lung disease, coronary artery disease, congestive heart failure, or valvular heart disease.*

lung disease, coronary artery disease, congestive heart failure, and valvular heart disease. Cardiopulmonary disease was defined as the presence of at least one of the aforementioned conditions except cigarette smoking.

Laboratory test results collected for this analysis focused on the first ABG and PO measurements obtained within the 48 hours of presentation to a study site. Although this time window may seem broad, >90% of ABG and PO measurements were taken on the same calendar date as the day of admission. Whether a patient was receiving supplemental oxygen at the time of ABG or PO measurement was also recorded. Hypoxemia was defined as partial pressure of oxygen (PaO_2) <60 mm Hg by ABG or oxygen saturation ($Sa\ O_2$) <90% for non–African Americans and <92% for African Americans by PO. Use of distinct thresholds to define oxygen saturation by race was based on observations reported that hypoxemia is present at a higher oxygen saturation in people with darker skin pigmentation.[8] A patient was considered hypoxemic if either test was abnormal, as either result was likely to prompt a therapeutic action by the physician.

Copies of initial chest radiographs used for the diagnosis of pneumonia at each study site were independently reviewed by a 3-member panel of staff radiologists at UPMC who had no patient-specific clinical information. For all patients with an infiltrate, further characterization of the radiograph (i.e., number of lobes involved, unilateral or bilateral infiltrates, and presence of pleural effusion) was performed by one panel member using a standardized protocol.[9]

For descriptive purposes, severity of illness at presentation was quantified by means of a validated prediction rule for 30-day mortality and medical complications in patients with CAP.[1] This rule was based on 3 demographic characteristics, 5 comorbid illnesses, 5 physical examinations findings, and 7 laboratory and radiographic findings from the time of presentation. The rule classifies patients into 5 risk classes with 30-day observed mortality ranging from 0.1% for Class I (lowest risk) to 27.0% for Class V (highest risk) in the Pneumonia PORT cohort.[1]

Processes of Care and Medical Outcomes

Mortality at 30 days following the radiographic diagnosis of pneumonia was ascertained for all of the 2,276 study patients. For inpatients, length of hospital stay was determined for all patients discharged alive. Intensive care unit (ICU) admission for respiratory failure or hemodynamic compromise was also recorded for all inpatients. Subsequent hospitalization for outpatients and hospital readmission for inpatients were assessed at 30 days after radiographic diagnosis of pneumonia.

Statistical Methods

Descriptive statistics were used to compare the proportions of outpatients and inpatients that had an ABG and/or PO performed across study sites. These comparisons were performed using the Pearson χ^2 statistic, with a 2-tailed P value < .05 considered statistically significant. The κ statistic was used to compare the agreement between PO and ABG in defining hypoxemia in patients who had both tests performed while breathing room air.

Logistic regression analysis with a backward-stepping procedure was used to assess the association between treatment site and patient sociodemographic and clinical characteristics and the use of ABG and PO. The G statistic, which measures change in likelihood statistics between models, was used to eliminate all nonsignificant independent variables with a P value > .05. Six separate models were constructed with the following dependent variables and patient populations: 1) ABG use in outpatients, 2) PO use in outpatients, 3) use of either test in outpatients, 4) ABG use in inpatients, 5) PO use in inpatients, and 6) use of either test in inpatients. The independent variables are listed in Tables 2 and 3. Altered mental status was included in the models for inpatients only because very few outpatients had altered mental status. Patients with missing data for any of these independent variables were excluded from the regression models for inpatients. Because over half of outpatients were missing one or more vital sign measurements, 2 models were constructed for outpatients: 1 that included patients who were missing vital sign measurements and 1 that did not. In the model that included outpatients with missing vital signs, the value of these vital signs was coded as "missing." Almost every factor that was significant in the inclusive outpatient models remained significant with minimal changes in the magnitude of their associated odds ratios in the exclusive models. Therefore, only the models including all outpatients are presented. To minimize the effect of variability of test availability across treatment settings, an additional model was constructed for only outpatients seen in an emergency department.

Logistic regression analysis with a backward-stepping procedure was also used to assess the associations between patient sociodemographic and clinical characteristics and hypoxemia in all patients tested by ABG or PO while breathing room air. If both ABG and PO were performed, a patient was considered hypoxemic if at least 1 of the initial tests revealed hypoxemia while breathing room air. The independent variables in this model are listed in Table 4.

Once independent risk factors for hypoxemia were identified, patients were categorized by number of risk factors for hypoxemia. The percent of patients who received any test of arterial oxygenation and the prevalence of hypoxemia for those tested on room air were compared across risk strata based on the number of risk factors for hypoxemia. Patients without information on a particular risk factor were presumed to have that factor "absent."

Logistic and linear regression analyses were also used to assess the association between ABG and PO measurement and patient outcomes. The outcomes assessed were subsequent hospital admission (outpatients

Table 2. Factors Independently Associated with Arterial Blood Gas or Pulse Oximetry Measurement among Outpatients

Factors*	Patients with Test, %			Adjusted Odds Ratio for Test (95% CI†)		
	Arterial Blood Gas (*n* = 45)	Pulse Oximetry (*n* = 172)	Either Test (*n* = 198)	Arterial Blood Gas	Pulse Oximetry	Either Test
Demographic						
Age, y						
≤50	4.1	18.7	21.4	1.0	ns‡	1.0
51–70	4.2	18.9	20.5	1.5 (0.7 to 3.6)	ns‡	1.6 (1.0 to 2.7)
>70	9.3	14.4	19.5	3.3 (1.5 to 7.2)	ns‡	2.0 (1.0 to 3.7)
Study Site						
UPMC§	3.6	57.8	59.6	1.0	1.0	1.0
SFMC§	4.1	42.9	42.9	1.1 (0.2 to 6.0)	0.8 (0.4 to 1.9)	0.8 (0.3 to 1.8)
MGH§	6.5	12.5	15.4	3.0 (1.0 to 8.5)	0.2 (0.1 to 0.4)	0.2 (0.1 to 0.4)
HCHP§	0.0	13.3	13.3	0.0	0.3 (0.2 to 0.7)	0.3 (0.1 to 0.6)
VGH§	5.4	9.5	13.7	2.2 (0.8 to 6.3)	0.1 (0.1 to 0.2)	0.2 (0.1 to 0.3)
Clinical						
Cardiopulmonary disease						
No	4.5	16.3	19.2	ns‡	1.0	ns‡
Yes	5.7	25.8	27.8	ns‡	1.6 (1.0 to 2.6)	ns‡
Dyspnea						
No	3.2	12.6	14.2	ns‡	1.0	1.0
Yes	5.5	21.1	24.4	ns‡	1.6 (1.0 to 2.5)	1.9 (1.2 to 2.9)
Respiratory rate, per minute						
<25	7.6	32.6	36.7	1.0	1.0	1.0
25–29	16.7	43.3	56.7	2.4 (0.8 to 7.0)	1.4 (0.6 to 3.1)	2.0 (0.0 to 4.5)
≥30	36.4	63.6	81.8	8.3 (2.1 to 33.3)	3.2 (0.8 to 12.4)	6.5 (1.3 to 32.3)
Not recorded	0.6	2.1	2.6	0.1 (0.0 to 0.2)	0.1 (0.1 to 0.3)	0.1 (0.1 to 0.3)
Heart rate, per minute						
<125	6.8	26.5	30.3	ns‡	1.0	1.0
≥125	7.7	34.6	42.3	ns‡	1.8 (0.7 to 4.8)	2.0 (0.8 to 5.2)
Not recorded	0.6	0.6	1.0	ns‡	0.1 (0.0 to 0.4)	0.1 (0.0 to 0.4)

** Patients missing vital sign measurements were included and labeled as "not recorded." Patients missing other data (<1%) were excluded from the analysis. The following independent variables were considered in this logistic regression: age, gender, race, treatment site, membership in a health maintenance organization, dyspnea, respiratory rate, pulse, temperature, systolic blood pressure, smoking status, and underlying cardiopulmonary disease.*

† CI denotes confidence interval.

‡ ns denotes not statistically significant.

§ UPMC indicates University of Pittsburgh Medical Center; SFMC, St. Francis Medical Center; MGH, Massachusetts General Hospital; HCHP, Harvard Community Health Plan–Kenmore Center; VGH, Victoria General Hospital.

only), ICU admission for respiratory failure or hemodynamic compromise (inpatients only), length of hospital stay (inpatients only), and 30-day mortality (outpatients and inpatients). In these analyses, the independent variables used to statistically control for severity at presentation were the same as those used in the hypoxemia modeling. With these variables used to control for severity, the use of either test and the results of the test (when available) were added as additional variables in the model. Differences in the G statistics for logistic regression and R^2 for the linear regression for models were used to assess the significant association between use of either test, abnormal results of the test, and patient outcomes.

RESULTS

Baseline Patient Characteristics

Among the 944 outpatients, 33% were older than age 50, 21% had underlying cardiopulmonary disease, and 88% were in the lowest 2 severity risk classes (Table 1). Among the 1,332 inpatients, 75% were older than age 50, 54% had underlying cardiopulmonary disease, and 50% were in the 2 highest severity risk classes.

Variations in ABG and PO Use Across Treatment Sites

Overall, 21.0% of outpatients had either an ABG or PO performed. While a consistently small percentage of outpatients had an ABG performed across institutions (0.0% at HCHP to 6.4% at MGH, $P = .07$), the proportion who had a PO performed varied dramatically from 9.4% at VGH to 57.8% at UPMC ($P < .0001$). For outpatients who presented to the emergency department at UPMC, 5.2% had ABG measurements compared to 16.5% at MGH ($P = .02$) and 64.9% had PO measurements compared to 36.3% at MGH ($P < .0001$).

Overall, 89.8% of inpatients had either ABG or PO performed. The proportion of inpatients who had either ABG or PO performed was nearly identical across

Table 3. Factors Independently Associated with Arterial Blood Gas or Pulse Oximetry Measurement among Inpatients

Factors*	Patients with Test, %			Adjusted Odds Ratio for Test (95% CI†)		
	Arterial Blood Gas (*n* = 904)	Pulse Oximetry (*n* = 907)	Either Test (*n* = 1,196)	Arterial Blood Gas	Pulse Oximetry	Either Test
Demographic						
Age, y						
≤50	55.2	64.7	80.7	1.0	ns‡	
51–70	71.7	68.5	91.6	2.0 1.4 to 2.8)	ns‡	2.7 (1.6 to 4.6)
>70	72.4	69.7	93.6	1.8 1.3 to 2.5)	ns‡	2.8 (1.8 to 4.4)
Admission via emergency dept.						
No	52.1	57.8	77.1	1.0	1.0	
Yes	70.5	69.8	91.9	1.8 (1.2 to 2.5)	1.7 (1.2 to 2.4)	2.8 (1.8 to 4.4)
Study Site						
UPMC§	49.2	85.1	90.9	1.0	1.0	
SFMC§	67.3	67.3	86.4	1.7 (1.0 to 2.8)	0.3 (0.2 to 0.5)	0.4 (0.2 to 0.9)
MGH§	73.1	71.3	90.3	2.5 (1.8 to 3.4)	0.4 (0.3 to 0.6)	0.7 (0.4 to 1.2)
VGH§	77.3	47.9	89.1	2.7 (1.9 to 3.9)	0.1 (0.1 to 0.2)	0.4 (0.2 to 0.7)
Clinical						
Cardiopulmonary disease						
No	59.3	62.9	84.7	1.0	1.0	
Yes	75.1	72.9	94.1	1.5 (1.1 to 2.0)	1.5 (1.1 to 1.9)	1.5 (1.0 to 2.4)
Dyspnea						
No	54.9	62.3	83.4	1.0	1.0	
Yes	72.3	70.0	92.0	1.8 (1.4 to 2.5)	1.4 (1.0 to 1.9)	2.3 (1.5 to 3.5)
Respiratory rate, per minute						
<25	60.3	63.4	85.7	1.0	1.0	
25–29	74.4	74.4	94.8	1.5 (1.0 to 2.1)	2.0 (1.4 to 3.0)	2.6 (1.3 to 5.1)
≥30	85.0	78.9	99.0	2.5 (1.7 to 3.7)	2.5 (1.8 to 3.6)	10.4 (3.2 to 33.5)
Heart rate, per minute						
<101	62.9	66.3	88.3	1.0	ns‡	ns‡
101–124	71.0	70.1	91.0	1.3 (1.0 to 1.8)	ns‡	ns‡
≥125	81.8	71.8	94.7	2.0 (1.3 to 3.2)	ns‡	ns‡

** Patients missing data (<1%) were excluded from the analysis. The following independent variables were considered in this logistic regression: age, gender, race, treatment site, membership in a health maintenance organization, admission through emergency department, subjective dyspnea, respiratory rate, pulse, temperature, systolic blood pressure, altered mental status, smoking status, and underlying cardiopulmonary disease.*

† CI denotes confidence interval.

‡ ns denotes not statistically significant.

§ UPMC indicates University of Pittsburgh Medical Center; SFMC, St. Francis Medical Center; MGH, Massachusetts General Hospital; VGH, Victoria General Hospital.

institutions (ranging from 86.4% at SFMC to 90.9% at UPMC, $P = .6$). However, ABG use ranged from 49.2% at UPMC to 77.3% at VGH ($P < .0001$), while PO use ranged from 47.9% at VGH to 85.1% at UPMC ($P < .0001$). Just under half of inpatients received both measures, ranging from 36.1% at VGH to 54.1% at MGH ($P < .001$).

Of the 615 inpatients who had both tests, information on the order in which the tests were performed was available for 297 (48.3%). Overall, 83.8% had PO performed first; however, this number varied substantially across institutions, from 68.0% at VGH to 97.6% at UPMC ($P < .0001$).

Factors Independently Associated with ABG or PO Measurement

For outpatients, 6 factors were independently associated with ABG or PO measurement; 5 (age, study site, dyspnea, respiratory rate, and heart rate) were associated with either ABG or PO measurement and 1 (underlying cardiopulmonary disease) with PO measurement only (Table 2).

For inpatients, 7 factors were independently associated with ABG or PO measurement; 6 (age, admission via the emergency department, study site, cardiopulmonary disease, dyspnea, and respiratory rate) were associated with use of either test, and 1 (heart rate) was associated with ABG measurement only (Table 3).

There was significant variation in the use of ABG and PO for both outpatients and inpatients across institutions. Increased use of 1 test was often associated with decreased use of the other. Overall, outpatients at MGH, HCHP, and VGH were less likely to receive either test compared to UPMC or SFMC. This difference reflects more use of pulse oximetry at the 2 Pittsburgh sites. Inpatients at SFMC and VGH were less likely to receive either test compared to patients at UPMC (Table 3).

Table 4. Factors Independently Associated with Arterial Hypoxemia at Presentation Determined by Arterial Blood Gas or Pulse Oximetry

Factors†	Adjusted Odds Ratio for Hypoxemia,* N = 1,090‡ (95% CI§)
Age >30 years	3.2 (1.7 to 5.9)
Respiratory rate >24/min	2.3 (1.8 to 3.0)
Infiltrate involving >1 lobe on chest radiograph	2.2 (1.7 to 2.9)
Altered mental status	1.6 (1.1 to 2.3)
Chronic obstructive pulmonary disease	1.9 (1.4 to 2.6)
Congestive heart failure	1.5 (1.0 to 2.1)

* *Hypoxemia was defined as PaO_2 <60 mm Hg or SaO_2 <90% for non–African-American patients and <92% for African-American patients. Patients breathing room air with results consistent with hypoxemia on either ABG or PO measurement were considered hypoxemic.*

† *The following independent variables were considered in the model: age, gender, race, nursing home residence, site, dyspnea, respiratory rate, pulse, temperature, systolic blood pressure, altered mental status, smoking status, congestive heart failure, coronary artery disease, chronic obstructive pulmonary disease, and number of lobes involved on chest radiograph. Patients at one of the sites (VGH treatment) were more likely to be hypoxemic (OR, 1.6; 95% CI, 1.2 to 2.2). This study-site variable was retained in the model used to estimate the above odds ratios.*

§ *CI denotes confidence interval.*

‡ *Patients missing one or more vital sign values (n = 31) were excluded from the analysis. For patients missing chest radiograph reports (n = 186), the number of lobes involved was presumed to be 1.*

Use of Supplemental Oxygen at the Time of ABG or PO Measurement

Of the 45 outpatients who had an ABG performed, only 10.5% were also receiving supplemental oxygen either by nasal cannula or face mask. The percentage receiving supplemental oxygen was even lower (3.6%) for the 172 outpatients who had PO performed. There was a greater likelihood of concurrent oxygen use for inpatients with an ABG performed (26.6%) than with a PO performed (21.2%).

Results of Arterial Blood Gas and Pulse Oximetry Measurements

For outpatients tested by ABG on room air (N = 34), PaO_2 ranged from 54 to 97 mm Hg (mean 74 mm Hg); for outpatients tested by PO on room air (N = 130), oxygen saturation ranged from 83% to 100% (mean, 95.5%). Only 2 (5.9%) outpatients tested by ABG and 5 (3.8%) tested by PO were hypoxemic while breathing room air. Two of the 7 outpatients receiving supplemental oxygen were hypoxemic based on either ABG or PO.

For inpatients tested by ABG on room air (N = 590), PaO_2 ranged from 26 to 100 mm Hg (mean, 61 mm Hg); for inpatients tested by PO on room air (N = 664), oxygen saturation ranged from 40% to 100% (mean, 90.9%). Nearly half (45.6%) of ABG measurements and one third (31.6%) of PO measurements revealed hypoxemia for inpatients while breathing room air. Hypoxemia was detected less often among inpatients receiving supplemental oxygen (21.7% tested by ABG and 23.4% tested by PO).

The association between the detection of hypoxemia by ABG and PO was assessed for the 297 (285 inpatients and 12 outpatients) patients who had both tests performed while breathing room air. The agreement rate was 72.7%, with a κ value of 0.44, indicating a moderate level of agreement.

Overall, 133 (14%) patients who had an ABG performed (with or without supplemental oxygen) were hypercapnic ($PaCO_2$ >45 mm Hg), 79 (8.3%) were acidemic (pH <7.35), and 54 were both hypercapnic and academia. About three quarters of the acidemic (77.2%) and hypercapnic (72.2%) patients had underlying cardiopulmonary disease. Of the 54 patients with respiratory acidemic, 29 (53.7%) were not hypoxemic based on the results of that ABG.

Factors Independently Associated with Arterial Hypoxemia

Of the 1,121 patients with an ABG or PO performed within 48 hours of presentation while breathing room air, 405 (36.1%) had evidence of arterial hypoxemia on at least 1 test. Six factors were independently associated with the finding of hypoxemia in these patients: age >30 years, chronic obstructive pulmonary disease, congestive heart failure, respiratory rate >24 per minute, altered mental status, and radiographic infiltrate involving >1 lobe (Table 4).

For outpatients, the prevalence of hypoxemia ranged from 1.3% for the 76 patients with 1 risk factor for hypoxemia to 18.2% for the 11 outpatients with 3 or more risk factors (Table 5). For inpatients, the prevalence of hypoxemia ranged from 13% among the 23 inpatients with no risk factors to 54.6% among the 425 inpatients tested with 3 or more risk factors. Of the 210 outpatients who had 2 or more risk factors, 146 (69.5%) did not have either an ABG or a PO performed, yet 8.3% of these patients who were tested were hypoxemic (Table 5).

Association of Patient Outcomes with ABG and PO Measurement

Outpatients who had either an ABG or PO performed (N = 198) were more likely to be subsequently admitted to a hospital than patients who had neither test performed (17.2% vs 5%; P < .0001). This difference in subsequent hospitalization remained statistically significant after controlling for comorbid conditions (including cardiopulmonary disease) and other markers of severity of illness at initial presentation. There were no statistically significant differences in 30-day mortality for outpatients based on ABG or PO measurement ($\leq$1% in all groups).

As shown in Table 6, inpatients who had either ABG or PO performed and whose supplemental O_2 status was

Table 5. Relationship Between ABG and PO Testing and the Risk of Hypoxemia among Outpatients and Inpatients

No. of Risk Factors for Hypoxemia*	Total	Not Tested		Tested on Room Air		If Tested on Room Air, % Hypoxemic§
		n†	%†	n‡	%‡	
Outpatients						
None	186	153	82.3	28	15.1	7.1
One	548	447	81.6	76	13.9	1.3
Two	172	123	71.5	37	21.5	5.4
Three or more	38	23	60.5	11	28.9	18.2
Total	944	746	79.0	152	16.1	4.6
Inpatients						
None	39	15	38.5	23	58.9	13.0
One	313	63	20.1	209	66.8	24.2
Two	420	44	10.5	312	74.3	35.9
Three or more	560	14	2.5	425	75.9	54.6
Total	1332	136	10.2	969	72.7	41.1

** Number of risk factors denotes the number of independent risk factors for arterial hypoxemia at presentation. Independent risk factors for hypxoemia were: age >30 years, chronic obstructive pulmonary disease, congestive heart failure, respiratory rate >24, altered mental status, and infiltrate involving >1 lobe on chest x-ray. Site of care was statistically controlled for but bed not used as a risk factor in the analysis.*

† N denotes the total number of outpatients or inpatients with neither ABG nor PO performed in a given risk stratum. % denotes the percentage of outpatients or inpatients with neither an AB G nor a PO performed in a given risk stratum.

‡ N denotes the number of outpatients and inpatients with a given total number of risk factors with either an ABG or PO performed while breathing room air. % denotes the percentage of outpatients and inpatients with a given total number of risk factors with either an ABG or PO performed while breathing room air. Percentages across columns do not add to 100% because patients who received a test on supplemental oxygen are not shown.

§ % denotes the percentage of outpatients and inpatients within a risk stratum with evidence of arterial hypoxemia (defined as a PaO_2 <60 mm Hg or SaO_2 <90% for non–African-American patients and <92% for African-American patients).

known (N = 1,105) were more likely to be admitted to an ICU for management of hemodynamic compromise or respiratory failure than patients who received neither test (19.5% vs 3.7%; $P < .001$). These differences remained statistically significant even after controlling for severity of illness at presentation ($\chi^2[df = 1] = 9.78$; $P \leq .01$). There were no significant differences in mortality or length of stay based on obtaining ABG or PO measurements. However, inpatients who were hypoxemic on room-air based on either an abnormal ABG or PO had higher rates of ICU admission (26.3% vs 10.7%; $P < .001$), higher mortality (12.3% vs 3.9%; $P < .001$), and longer mean length of stay (11.1 vs 8.7 days; $P < .001$) than patients who were tested and not hypoxemic on room air.

DISCUSSION

This prospective, multicenter study demonstrated wide variation in the use of ABG and PO across study sites in the initial management of CAP even after controlling for differences in patient characteristics and severity of illness. One tenth of inpatients and over three quarters of outpatients had no test of arterial oxygenation performed. Though arterial hypoxemia at presentation was independently associated with 6 easily detected risk factors, even patients with none of these risk factors had a 7% (outpatients) to 13% (inpatients) prevalence of arterial hypoxemia when tested on room air. Furthermore, 70% of all outpatients with 2 or more risk factors for hypoxemia had neither ABG or PO performed. These findings suggest the need to increase the measurement of arterial oxygenation in patients with CAP, particularly for those treated in the outpatient setting.

Only 21% of outpatients received either ABG or PO, with evidence of large variation in test ordering across study sites. When a measure of arterial oxygenation was performed in the outpatient setting, it was most often PO, likely due to the greater availability of PO testing devices in outpatient, and emergency department settings, and the less invasive nature and lower cost of this test. Apart from hospital site and treatment in an emergency department, performance of ABG or PO for outpatients was independently associated with increased age, underlying cardiopulmonary disease, dyspnea, tachypnea, and tachycardia.

In contrast to outpatients, 90% of inpatients received some measure of arterial oxygenation within 48 hours of presentation, with minimal variation across institutions. This frequency is similar to the proportion of inpatients that received an assessment of arterial oxygenation in the first 24 hours of presentation in a retrospective cohort limited to elderly Medicare inpatients with pneumonia.[6] Although nearly equivalent proportions of all inpatients received either ABG or PO, there was substantial variation in the individual use of ABG and PO across institutions. One institution relied much more heavily on PO than ABG, 1 more heavily on ABG than PO, and 2 about equally on ABG and PO. Although these data suggest that there is an inverse use of ABG and PO across institutions, what accounts for the dramatic variation is unclear.

Over the past 10 years PO use has grown rapidly. Measurement of arterial oxygen saturation by PO is readily available, noninvasive, inexpensive, and can provide useful results without delay. Some have argued that oxygen saturation determined by PO should be considered a fifth vital sign in certain patients and settings.[10,11] Our data suggest that routine use in patients suspected of CAP would detect clinically unrecognized hypoxemia. However, the accuracy of pulse oximeters has reported to vary with perfusion status, severe hypoxemia, patient motion, dyshemoglobinapathies, contrast dyes, skin pigmentation, and nail polish.[12–14] Historically, ABG analysis by cooximetry has been considered the gold standard for measuring arterial oxygenation.[13,15] Compared to PO, it is more invasive, more labor intensive, and cannot provide immediate or continuous results. However, unlike PO, ABG provides useful information about arterial pH and $PaCO_2$. In this study, 14% of patients who had ABG performed were

Table 6. Relationship between Arterial Oxygenation, Outcomes, and Process of Care for Inpatients

Test Status	Number of Patients*	30-day Mortality Rate		ICU Admission Rate		Mean (Median) Length of Stay in Days†	
No test performed	136	5.9%		3.7%		9.0 (7)	
ABG on room air	590	42 (7.1%)		95 (16.2%)		10.0 (8)	
Not hypoxemic	321	3.4%	$P < .002$§	9.1%	$P < .001$§	8.8 (7)	$P < .001$§
Hypoxemic‡	269	11.5%		24.6%		11.3 (8)	
PO on room air	664	48 (7.2%)		113 (17.1%)		9.2 (7)	
Not hypoxemic	454	5.3%	$P = .004$§	11.1%	$P < .001$§	8.4 (7)	$P < .001$§
Hypoxemic‡	210	11.4%		30.1%		10.9 (8)	
Either test on room air	969	71 (7.3%)		165 (17.1%)		9.7 (8)	
Not hypoxemic	571	3.9%	$P = .001$§	10.7%	$P < .001$§	8.7 (7)	$P < .001$§
Hypoxemic‡	398	12.3%		26.3%		11.1 (8)	

* *Patients who had either ABG or PO, but whose supplemental oxygen status was unknown (*n *= 91) were excluded from this table and analysis.*
† *Includes only patients discharged alive.*
‡ *Hypoxemia was defined as a* PaO_2 *<60 mm Hg or* SaO_2 *<90% for non–African-American patients and <92% for African-American patients. Patients breathing room air with results consistent with hypoxemia on either ABG or PO measurement were considered hypoxemic.*
§ P *value of the statistical test that compared patients within specific categories with and without hypoxemia.*

discovered to have hypercapnia, and 5.7% respiratory acidemia. For an important minority, these findings could not have been predicted based on comorbid cardiopulmonary disease and were independent of documented arterial hypoxemia. Thus, use of ABG may have allowed clinicians to identify impending ventilatory failure in patients in whom this condition may not have been recognized through reliance on PO alone.

This study identified 6 independent risk factors for hypoxemia in patients with CAP: age >30 years, chronic obstructive pulmonary disease, congestive heart failure, respiratory rate >24 per minute, altered mental status, and infiltrate on chest radiograph involving more than 1 lobe. While patients with 3 or more of the risk factors were more likely to be hypoxemic (18.2% for outpatients and 54.6% for inpatients), 10% of 51 patients (7.1% of 28 outpatients and 13% of 23 inpatients) who had none of these risk factors were hypoxemic when tested. Thus, based on our data, it is not possible to identify a subset of patients for whom ABG or PO testing is unnecessary because of the absence of independent risk factors for hypoxemia. We acknowledge that the high prevalence of hypoxemia observed in this study is likely to reflect physician selection of patients most likely to have an abnormal test result. If all CAP patients had been tested by ABG or PO, the overall prevalence of hypoxemia would likely have been lower.

Use of either ABG or PO increased a patient's risk for having more intensive subsequent care, either subsequent hospital admission for outpatients or ICU admission for inpatients. There are 2 possible explanations for these findings. The most likely explanation is that older and more severely ill patients were selected for testing, and, therefore, were at increased risk of a more complicated outcome. This explanation is supported by a previous report in an elderly population of patients with pneumonia whose mortality was higher in patients with an ABG performed.[6] Alternatively, testing may have allowed the discovery of underlying pathophysiologic findings (i.e., hypoxemia, hypercapnia, or acidemia) which led to more intensive forms of treatment.

This study has several limitations that must be acknowledged. First, not all patients received ABG or PO testing. Although this allowed characterization of factors associated with test ordering, it limited characterization about risk factors for hypoxemia to patients who actually received an ABG or PO measurement. Thus, it is not possible to determine the proportion of patients not tested who were actually hypoxemic. Second, characterization of the factors associated with testing was limited by the fact that whether an outpatient was treated in an ED or non-ED setting was only available for two institutions (UPMC and MGH). Third, more definite conclusions about the use of ABG versus PO in the management of CAP could not be made, because the relative order of these tests in the overall process of patient management was not consistently documented. Finally, while it is clear that there were no formal guidelines on ABG or PO use at the study sites, no formal data about test availability were collected. It is likely that many nonemergency department outpatient sites did not have ready access to ABG or PO measurement, which could have altered test ordering patterns.

In summary, this study revealed wide variation in the use of ABG and PO across treatment sites and identified the demographic and clinical variables associated with ordering these tests and the factors independently associated with arterial hypoxemia at presentation. Even in the absence of risk factors for hypoxemia, 10% of these patients tested were found to be hypoxemic. Thus, identifying a population for whom testing is unnecessary because of a low prevalence of hypoxemia may not be possible. These findings suggest that more widespread use of ABG or PO, particularly in the outpatient setting, is necessary because of the significant proportion of patients who had no risk factors for hypoxemia who were, nevertheless, hypoxemic when tested. For most CAP patients, PO, the less invasive, less costly, and more readily available

test, is the most appropriate measure. In these patients hypoxemia is the principal clinical concern and response to interventions, such as supplemental oxygen, can be assessed immediately. However, ABG should be considered for patients with underlying cardiopulmonary disease, for those for whom ventilatory failure is of clinical concern, and if other reported sources of error for PO are present.[16]

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