Effect of Increasing the Intensity of Implementing Pneumonia Guidelines

A Randomized, Controlled Trial

Donald M. Yealy, MD; Thomas E. Auble, PhD; Roslyn A. Stone, PhD; Judith R. Lave, PhD; Thomas P. Meehan, MD, MPH; Louis G. Graff, MD; Jonathan M. Fine, MD; D. Scott Obrosky, MS; Maria K. Mor, PhD; Jeff Whittle, MD, MPH; and Michael J. Fine, MD, MSc*

Background: Despite the development of evidence-based pneumonia guidelines, limited data exist on the most effective means to implement guideline recommendations into clinical practice.

Objective: To compare the effectiveness and safety of 3 guideline implementation strategies.

Design: Cluster-randomized, controlled trial.

Setting: 32 emergency departments in Pennsylvania and Connecticut.

Patients: 3219 patients with a clinical and radiographic diagnosis of pneumonia.

Interventions: The authors implemented a project-developed guideline for the initial site of treatment based on the Pneumonia Severity Index and performance of evidence-based processes of care at the emergency department level. Guideline implementation strategies were defined as low (n = 8), moderate (n = 12), and high intensity (n = 12).

Measurements: Effectiveness outcomes were the rate at which low-risk patients were treated on an outpatient basis and the performance of recommended processes of care. Safety outcomes included death, subsequent hospitalization for outpatients, and medical complications for inpatients.

Results: More low-risk patients (n = 1901) were treated as outpatients in the moderate-intensity and high-intensity groups than in the low-intensity group (high-intensity group, 61.9%; moderate-intensity group, 61.0%; low-intensity group, 37.5%; P = 0.004). More outpatients (n = 1125) in the high-intensity group received all 4 recommended processes of care (high-intensity group, 60.9%; moderate-intensity group, 28.3%; low-intensity group, 25.3%; P < 0.001); more inpatients (n = 2076) in the high-intensity group received all 4 recommended processes of care (high-intensity group, 44.3%; moderate-intensity group, 30.1%; low-intensity group, 23.0%; P < 0.001). No statistically significant differences in safety outcomes were observed across interventions.

Limitations: Twenty percent of eligible patients were not enrolled, and data on effectiveness outcomes were not collected before the trial.

Conclusions: Both moderate-intensity and high-intensity guideline implementation strategies safely increased the proportion of low-risk patients with pneumonia who were treated as outpatients. The high-intensity strategy was most effective for increasing the performance of the recommended processes of care for outpatients and inpatients.

Ann Intern Med. 2005;143:881-894. www.annals.org

For author affiliations, see end of text.

*For the names of individuals who served as project coordinators, local study investigators, research staff, and study research nurses, see the Appendix, available at www.annals.org.

Physicians frequently overestimate the probability of death in low-risk patients with pneumonia, leading to potentially unnecessary, costly hospitalizations instead of outpatient treatment, which is often preferred (1–3). The Pneumonia Severity Index (PSI) accurately identifies patients at low risk for short-term mortality (4). Two effectiveness trials have demonstrated that implementation of the PSI reduces the proportion of low-risk patients admitted to the hospital from the emergency department (5, 6). A more recent efficacy trial showed equivalent health outcomes and greater satisfaction with medical care among patients in PSI risk classes II and III who were randomly assigned to outpatient treatment (7). However, the best methods to implement the PSI into clinical practice remain unclear.

Observational studies have linked performance of blood cultures (8, 9), rapid initiation of antibiotic therapy (9, 10), and appropriate selection of antibiotic therapy with improved short-term survival for patients hospitalized for pneumonia (11, 12). Other studies have identified the assessment of arterial oxygenation as a salient process of care because of its prognostic value and pivotal role in site-of-treatment decisions (1, 13). These advances have

See also:

Print

Editors' Notes 882
Summary for Patients I-30

Web-Only

Appendix
Conversion of figures and tables into slides

Improving Patient Care is a special section within *Annals* supported in part by the U.S. Department of Health and Human Services (HHS) Agency for Healthcare Research and Quality (AHRQ). The opinions expressed in this article are those of the authors and do not represent the position or endorsement of AHRQ or HHS.

Context

The effects of intensified efforts to translate guidelines into practice are poorly understood.

Content

Thirty-two emergency departments were randomly assigned to low-intensity, moderate-intensity, and high-intensity strategies for implementing guidelines for community-acquired pneumonia. More low-risk patients were appropriately treated as outpatients in moderate-intensity and high-intensity implementation sites. Adherence to recommended processes of care was better with the high-intensity intervention. Mortality rates, hospitalization after initial outpatient treatment, and inpatient medical complications were similar irrespective of guideline implementation strategy.

Implications

The most intense guideline implementation strategy resulted in the highest adherence to recommended processes of care.

—The Editors

contributed to the development of evidence-based practice guidelines for pneumonia that typically recommend all of these initial processes of care for hospitalized patients and a subset of them for outpatients (14–16). The Centers for Medicare & Medicaid Services and the Joint Commission on Accreditation of Healthcare Organizations have adopted these processes of care as pneumonia quality indicators, and the latter organization uses these indicators as a part of its national hospital accreditation program (17, 18).

Despite these advances, the overall quality of care for pneumonia ranks 20th among 25 common adult ambulatory care problems (19). Although quality improvement studies demonstrate increased adherence to several processes of care, such as timely initiation of antibiotic therapy and performance of blood cultures for inpatients (8, 20–22), these studies are of limited usefulness because they were performed in few study sites or featured nonrandomized designs. We compared the effectiveness and safety of 3 pneumonia guideline implementation strategies. We hypothesized that a high-intensity intervention, in comparison with moderate-intensity and low-intensity interventions, would increase the number of low-risk patients treated as outpatients and the number of higher-risk patients hospitalized for care and that patient safety would not be compromised with these approaches. We also wanted to determine whether a high-intensity or moderate-intensity intervention would improve the performance of the recommended processes of care.

METHODS

Study Design and Patient Eligibility

We conducted a cluster-randomized trial at emergency departments in Connecticut ($n = 16$) and Pennsylvania ($n = 16$). Our nonrandom criteria for participation of study sites were 1) location in southwestern Pennsylvania or Connecticut; 2) annual volume of more than 15 000 patient visits; and 3) willingness to be randomly assigned to any of the 3 study interventions. All relevant institutional review boards approved the trial, and all enrolled patients provided informed consent. We previously reported the study methods (23).

Emergency department medical providers recruited patients 7 days per week between 15 January 2001 and 31 December 2001. Eligible patients were 18 years of age or older with a clinical diagnosis of pneumonia and a new pulmonary infiltrate that had been identified on radiography by the emergency department provider or an on-site radiologist. We excluded patients who were considered to have hospital-acquired pneumonia; immunosuppression; specified comorbid conditions (such as cystic fibrosis or pulmonary tuberculosis) that were distinguishable from pneumonia; or psychosocial conditions or substance abuse problems that were incompatible with outpatient treatment, enrollment, or follow-up. We also excluded patients who were incarcerated, homeless, pregnant, previously enrolled, or enrolled in a competing research protocol (23).

Practice Guideline

The study practice guideline consisted of recommendations for the initial site of treatment and processes of care after presentation to the emergency department (23) (**Table 1**). We developed the guideline with assistance from national experts in pneumonia with clinical backgrounds in internal and family medicine, emergency medicine, pulmonary medicine, and infectious disease. The guideline was based on expert consensus reached through a systematic review of the literature and was approved by medical providers at all participating emergency departments.

We used the level of arterial oxygenation and PSI risk class (**Table 1**) to determine site-of-treatment recommendations (4, 23). Patients without any of the 11 prognostic factors in the first step of the PSI were assigned to risk class I. The remaining patients were assigned to risk classes II through V on the basis of their total risk points for the 20 PSI variables. Missing data for all prognostic factors were assumed to be normal (4). Outpatient therapy was recommended for all low-risk patients, defined as those in risk classes I through III who had no evidence of clinically significant arterial oxygen desaturation (oxygen saturation <90% or PO_2 <60 mm Hg) at presentation; the guideline specified medical and psychosocial contraindications to outpatient treatment of this group of patients (**Table 1**). Inpatient therapy was recommended for all higher-risk patients, defined as those with documented arterial oxygen desaturation or those in risk classes IV or V.

The guideline recommended an assessment of all patients' arterial oxygenation by pulse oximetry or measurement of arterial blood gas level (Table 1). According to the guidelines, the first dose of antibiotic therapy was to be given in the emergency department for outpatients and within 4 hours of presentation to the emergency department for inpatients (10, 15). For inpatients, 2 blood cultures were to be obtained before antibiotic therapy was initiated (14–16). The recommended antibiotic agents for all patients were consistent with current medical specialty society guideline recommendations (14–16). The definition of guideline-compliant antibiotic therapy varied by nursing home residence for outpatients (both in the emergency department and on discharge) and by admission to the intensive care unit for inpatients.

Randomization and Study Interventions

After stratifying emergency departments by state, teaching status, and annual volume, our statistician randomly assigned these departments to low-intensity, moderate-intensity, and high-intensity guideline implementation strategies in the ratio of 2:3:3, respectively. All interventions were implemented at the emergency department level and were conducted in collaboration with the state quality improvement organizations in Pennsylvania and Connecticut. The low-intensity strategy (used by 8 emergency departments) reflected the quality improvement methods typically used by the collaborating quality improvement organizations. During the year before patient enrollment, these organizations collected hospital-specific performance data for a national pneumonia quality improvement program; reports containing these data were then distributed to all emergency department and quality improvement directors (17). These baseline data included the proportion of hospitalized Medicare patients who were at low risk for short-term mortality on the basis of PSI class and who received each of the 4 inpatient processes of care shown in Table 1. The state-specific quality improvement organizations asked each of the hospital directors to develop a quality improvement plan that addressed the guideline-recommended processes of care. Because participation was voluntary, hospital directors could decide that such a plan was unwarranted and were not required to implement or evaluate their plans. Sites that did not provide plans received follow-up letters that pointed out areas for pneumonia quality improvement and effective approaches to achieve such improvements. In addition, the research team mailed the practice guideline and supporting literature to all medical providers at these emergency departments.

The 12 emergency departments in the moderate-intensity arm received all of the low-intensity strategies. In addition, the state-specific quality improvement organizations asked that each hospital's plan address the initial site of treatment for pneumonia. Before patient enrollment, the research team also conducted an on-site educational session to teach medical providers how to use the PSI to guide the initial site of treatment and to reinforce all guideline recommendations.

Table 1. **Summary of Guideline Recommendations for the Initial Site of Treatment and Processes of Care for Patients with Pneumonia**

Initial site of treatment*
Outpatient treatment recommended for all low-risk patients (risk classes I through III) without evidence of clinically significant arterial oxygenation desaturation (oxygen saturation <90% or PO_2 <60 mm Hg) at presentation
Inpatient treatment recommended for all higher-risk patients (risk classes IV or V) or patients with documented arterial desaturation at presentation
Processes of care for outpatients†
Assess arterial oxygenation at presentation (by pulse oximetry or arterial blood gas)
Administer first antibiotic dose in the emergency department
Initiate appropriate empirical oral antibiotic therapy in the emergency department‡
Therapies for outpatients not residing in nursing homes
Macrolide alone
Fluoroquinolone or doxycycline alone
Therapies for outpatients residing in nursing homes
Macrolide alone
Fluoroquinolone alone
β-Lactam alone
β-Lactam plus macrolide or fluoroquinolone
Prescribe appropriate antibiotic therapy on discharge from the emergency department‡
Processes of care for inpatients†
Assess arterial oxygenation at presentation (by pulse oximetry or arterial blood gas)
Perform 2 blood cultures before initiating antibiotic therapy
Administer first antibiotic dose in the emergency department within 4 hours of presentation
Initiate appropriate empirical antibiotic therapy‡
Therapies for inpatients not admitted to an intensive care unit
Fluoroquinolone alone
Cephalosporin (intravenous) plus macrolide or fluoroquinolone
β-Lactam/β-lactamase inhibitor (intravenous) plus macrolide or fluoroquinolone
Therapies for inpatients admitted to an intensive care unit
Cephalosporin (intravenous) plus macrolide or fluoroquinolone
β-Lactam/β-lactamase inhibitor (intravenous) plus macrolide or fluoroquinolone

* Contraindications to outpatient treatment of low-risk patients were clinical and psychosocial factors that could affect compliance with oral antibiotics, frailty or severe neuromuscular disease, serious comorbid illness, extreme abnormalities in vital signs or laboratory values, and suppurative infections.
† Processes of care that were recommended for outpatients and inpatients refer to the actual site of treatment after discharge from the emergency department as determined by the treating medical provider, regardless of the guideline-recommended site of treatment as determined by arterial oxygenation and risk class.
‡ Recommended macrolides are azithromycin, clarithromycin, and erythromycin; recommended fluoroquinolones are high-dose ciprofloxacin, gatifloxacin, levofloxacin, moxifloxacin, and ofloxacin; recommended oral β-lactams/cephalosporins are amoxicillin–clavulanate, cefpodoxime, cefprozil, and cefuroxime; recommended intravenous cephalosporins are cefuroxime, cefotaxime, ceftriaxone, and cefepime; and recommended intravenous β-lactam/β-lactamase inhibitors are ampicillin–sulbactam and piperacillin–tazobactam.

The 12 emergency departments in the high-intensity group received all low-intensity and moderate-intensity strategies, real-time reminders, medical provider audits and feedback, and continuous quality improvement activities that were implemented throughout the study period (24–26). All medical providers received a 1-page paper reminder (retrieved on their own or provided by an emer-

gency department nurse) each time they treated an enrolled patient. The reminders included instructions for assigning risk points for each PSI prognostic factor, a table linking the calculated PSI risk score to a risk class, an initial site-of-treatment recommendation for each risk class, and the recommended processes of care (27). This reminder form also included an estimated mortality rate for each PSI risk class and a disclaimer stating that the ultimate site-of-treatment decision should be consistent with the medical provider's clinical judgment (4). Written audits and feedback, which were provided to the responsible medical provider within 1 week of treating each enrolled patient, documented the level of compliance with the guideline site-of-treatment and processes-of-care recommendations (24–26, 28). These documents also sought reasons for noncompliance from the providers.

Continuous quality improvement consisted of "plan–do–study–act" (PDSA) cycles that were conducted within each of the 12 emergency departments (26). A study investigator familiar with this form of quality improvement provided a half-day training session for emergency department directors of all high-intensity sites. The training session defined the director's lead role on the PDSA team, made recommendations for additional team membership, and provided an overview of recommended methods to conduct PDSA cycles. In addition to its leader, each PDSA team consisted of 2 to 6 individuals with backgrounds in medicine, nursing, and quality improvement. The teams collected real-time data. Every 2 months, the teams received site-specific reports summarizing performance data for each of the guideline-recommended processes of care; these reports were individualized so that data remained anonymous for all high-intensity sites except the recipient's own. The teams were asked to meet every 2 months with study investigators and state representatives from quality improvement organizations to review their institutions' compliance with guideline recommendations and to devise ways to improve adherence.

All emergency departments assigned to the low-intensity and moderate-intensity groups received financial support for a half-time research assistant to recruit patients and collect baseline data. Those assigned to the high-intensity group received support for a half-time emergency department nurse to recruit patients, collect baseline data, institute reminders, conduct audits and feedback, and organize the local PDSA cycles.

Data Collection

Research staff prospectively collected patient demographic data and characteristics of participating emergency department medical providers and emergency departments (23). Emergency department providers assessed the severity of each patient's illness at presentation by using the PSI and the level of arterial oxygenation (23). Emergency department providers in the low-intensity and moderate-intensity groups used a checklist to document the 20 PSI prognostic factors but did not calculate a risk score. Providers in the high-intensity group documented the presence of these factors on a different form that included a site-of-treatment reminder and instructions detailing an explicit method for risk-score calculation.

The primary effectiveness outcomes were the proportions of low-risk and higher-risk patients who were treated as outpatients, the performance rates of the recommended processes of care for outpatients and inpatients, and the number of processes performed (**Table 1**). We defined outpatient treatment as discharge from the emergency department to any outpatient setting or discharge from an emergency department observation unit within 24 hours of presentation; we defined inpatient treatment as hospital admission, transfer from an emergency department to an inpatient hospital observation unit, or admission to an emergency department observation unit with discharge to any setting more than 24 hours after presentation. Safety outcomes included all-cause mortality, serious medical complications for hospitalized low-risk patients, reasons for admission to an intensive care unit for inpatients, and subsequent hospitalizations for outpatients (6, 23). We also assessed patient satisfaction with care and the rates at which patients returned to work and usual activities.

We collected the primary and secondary outcomes by using a structured review of patient medical records and telephone interviews with patients that focused on their experiences during the first 30 days after the index emergency department presentation (23). Interviewers and patients were unaware of their hospital's intervention group assignment; chart reviewers could not be blinded to intervention group.

Statistical Analysis

We estimated that we would need 96 eligible patients per hospital (3072 in total) to achieve 80% power to detect a 12% difference across the intervention groups for the site-of-treatment decision among low-risk patients. We used a cluster-randomization design with a 0.05 significance level test and 2 degrees of freedom (23, 29). The target sample size included an adjustment of 30% to account for the clustering of patients within providers (29). For the site-of-treatment decision, this study achieved greater than 80% power to detect differences of 10% between high-intensity and moderate-intensity groups and differences of 12% between high-intensity and low-intensity groups according to separate 1-tailed tests in which the α level was 0.025.

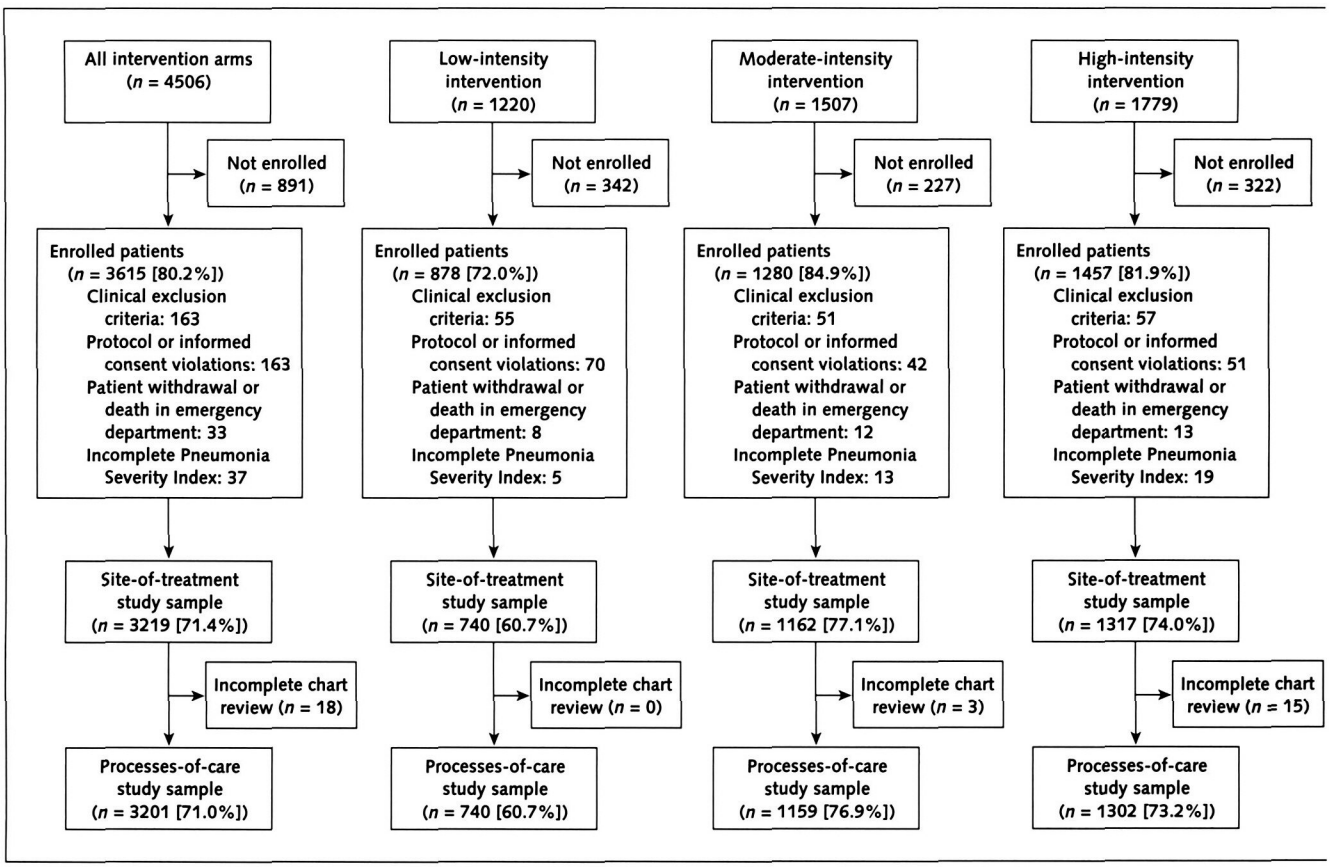
Because the site-of-treatment decision determines the inpatient and outpatient denominators for the process-of-care analyses, we estimated the power to detect the process-of-care outcomes under both the null and alternative hypotheses for the site-of-treatment decision. For all inpatient processes of care except assessment of arterial oxygenation, the sample size provides greater than 90% power to detect differences of 8% between the high-intensity and moder-

ate-intensity groups and greater than 80% power to detect differences of 8% between the high-intensity and low-intensity groups. Within the relatively smaller group of outpatients, the sample size provides at least 80% power to detect differences of 12% between the high-intensity and moderate-intensity groups and differences of 14% between the high-intensity and low-intensity groups. Because the anticipated rate of assessment of arterial oxygenation in all 3 groups was greater than 90% (9, 30), we did not design this trial to detect differences for this process of care.

We used 3-level logistic regression to analyze the binary effectiveness and safety outcomes, with the levels defined by patient, medical provider, and emergency department (31). We used the Metropolis–Hastings algorithm (a Markov chain Monte Carlo method) in MLwiN statistical software (Centre for Multilevel Modelling, London, England) to account for the cross-classification of the 28 providers who enrolled patients at more than 1 study site (32). Intervention group was included as a fixed effect in all models. We present unadjusted intervention comparisons for all effectiveness and safety outcomes in the appropriate patient subgroups. We considered low-risk and higher-risk patients separately for all site-of-treatment analyses because the guideline made different recommendations for each; similarly, we considered inpatients and outpatients separately in all process-of-care analyses because recommended processes differed by site of treatment. In addition, we calculated the odds ratios and associated 95% CIs for all pairwise comparisons of the effectiveness and safety outcomes across the 3 intervention groups, adjusted for state and severity of illness as defined by PSI risk class and arterial oxygen desaturation. The count of guideline-recommended processes of care for outpatients and inpatients was dichotomized as 4 versus 0 to 3 in the multilevel modeling. We analyzed the rates at which patients returned to work and usual activities by using multilevel, discrete proportional-odds models for grouped time-to-event data.

We assessed the effect of baseline imbalances in patient characteristics, provider volume, and emergency depart-

Figure 1. **Patient enrollment.**



Overall, 4506 eligible patients were identified, of which 3615 (80.2%) were initially enrolled. Following enrollment, 396 patients were excluded because of discovery of 1 or more clinical exclusion criteria not recognized at presentation (n = 163), enrollment protocol or informed consent violations (n = 163), patient withdrawal or death in the emergency department before an initial site of treatment was assigned (n = 33), and incomplete information required to assign risk class (n = 37). The most common protocol violations were enrollment of patients 1) managed by a study co-investigator in the low-intensity group (n = 47); 2) previously enrolled in the study (n = 32); and 3) participating in a competing research protocol (n = 29). The study population to assess the site of treatment consisted of 3219 (71.4%) patients, and the study population to assess initial processes of care consisted of 3201 (71.0%) patients.

Table 2. **Baseline Patient and Emergency Department Characteristics by Intervention Group**

Baseline Characteristic	Guideline Implementation Group			*P* Value*
	Low Intensity (n = 740)	Moderate Intensity (n = 1162)	High Intensity (n = 1317)	
Demographic data				
Median age, *y*	69	65	70	<0.001
Women, %	50.0	51.0	52.5	0.51
Race and ethnicity, %				
White, non-Hispanic	88.5	90.3	83.7	<0.001
Black, non-Hispanic	7.6	6.0	14.1	
Hispanic	3.1	3.1	1.8	
Other†	0.8	0.6	0.5	
Nursing home resident, %	4.1	3.5	7.0	<0.001
Health insurance, %				
Health maintenance organization	25.8	23.6	26.6	0.090
Fee for service	67.8	70.0	65.2	
Uninsured or unknown	6.4	6.5	8.2	
Comorbid illness, %				
Neoplastic disease	3.0	4.0	4.7	0.160
Liver disease	1.1	0.7	0.8	0.66
Congestive heart failure	11.6	10.6	16.6	<0.001
Cerebrovascular disease	7.6	6.8	8.0	0.50
Renal disease	7.7	4.4	6.9	0.005
Physical examination findings, %				
Altered mental status	7.6	5.5	8.4	0.020
Respiratory rate ≥30 breaths/min	11.2	10.1	12.5	0.150
Systolic blood pressure <90 mm Hg	3.4	2.2	3.0	0.30
Temperature <35 °C or ≥40 °C	10.0	7.2	6.8	0.030
Pulse ≥125 beats/min	10.5	9.5	11.2	0.38
Laboratory results, %‡				
Arterial pH level <7.35	3.5	2.8	2.5	0.51
Blood urea nitrogen level ≥10.7 mmol/L	15.1	13.7	13.9	0.72
Serum sodium level <130 mmol/L	4.3	4.3	3.7	0.70
Plasma glucose level ≥13.9 mmol/L (≥250 mg/dL)	5.0	6.4	4.5	0.180
Hematocrit <0.30	6.3	3.2	4.2	0.020
Oxygen desaturation	19.5	19.8	25.5	<0.001
Pleural effusion by radiograph	13.1	12.0	7.3	<0.001
Severity of illness, %§				
Low-risk	60.2	65.0	53.1	<0.001
Class I, no oxygen desaturation	18.5	24.4	21.0	
Class II, no oxygen desaturation	24.0	23.0	19.2	
Class III, no oxygen desaturation	17.7	17.6	12.9	
Higher-risk	39.8	35.0	46.9	
Class I–III with oxygen desaturation	7.0	7.5	9.1	
Class IV	25.8	21.0	29.6	
Class V	7.0	6.5	8.2	
Emergency department characteristics				
Participating facilities, *n*	8	12	12	
Median medical providers, *n*	16.0	19.5	24.5	0.110
Median annual visits, *n*	33 303	31 892	25 899	0.64
Urban location, %	100.0	83.3	91.7	0.77
Affiliated with a teaching hospital, %	50.0	50.0	50.0	‖
Pneumonia pathway used, %	62.5	66.7	66.7	1.00
Pneumonia order form used, %	12.5	41.7	50.0	0.33
Patients treated by residents, %	37.5	25.0	33.3	0.89

* Comparisons of patient and emergency department characteristics across intervention groups used 2-sided *P* values estimated with chi-square statistics for categorical variables and with Wilcoxon rank-sum tests for age. Exact *t*-tests were used for hospital characteristics.

† Other ethnicities include Asian/Pacific Islanders (n = 8), Native Americans or Alaskan Natives (n = 2), and uncategorized (n = 9).

‡ The estimation of abnormal laboratory results other than arterial oxygenation excludes the 698 patients in risk class I from all 3 intervention groups without arterial oxygenation desaturation because these data were not collected on patients in risk class I in the high-intensity intervention group. The data collection forms used in the high-intensity group assigned patients to risk class I without recording these data—a method consistent with the original derivation and validation of the Pneumonia Severity Index.

§ Severity of illness was based on risk class and level of arterial oxygenation. Clinically significant arterial oxygen desaturation was defined as PO_2 less than 60 mm Hg by blood gas analysis or oxygen saturation less than 90% by pulse oximetry.

‖ Emergency department randomization to intervention group was stratified by hospital teaching status.

ment characteristics (teaching status, annual volume, pneumonia pathways, pneumonia order forms, and treatment by residents) on the effectiveness outcomes. These analyses are not shown because they had minimal effects on our study results.

Role of the Funding Source

The funding source had no role in the design, conduct, or reporting of the study or in the decision to submit the manuscript for publication.

RESULTS

We initially enrolled 3615 (80.2%) of 4506 eligible patients (**Figure 1**); a median of 113 patients (interquartile range, 101 to 123) were enrolled per site. Compared with nonenrolled eligible patients, participants were younger (median age, 79 vs. 68 years) and less likely to reside in a nursing home (35.7% vs. 5.7%). We excluded 396 enrolled patients from the site-of-treatment analysis, most frequently because we discovered the presence of an exclusion criterion after enrollment or because of protocol or consent violations. Relatively fewer eligible patients were enrolled and more patients were excluded following enrollment in the low-intensity intervention group. The study samples consisted of 3219 (71.4%) patients (1901 low-risk and 1318 higher-risk) for site-of-treatment and 3201 (71.0%) patients (1125 outpatients and 2076 inpatients) for process-of-care analyses.

Baseline Characteristics

Patients in the moderate-intensity group tended to be younger than patients in the high-intensity and low-intensity groups; median ages were 65, 70, and 69 years, respectively (**Table 2**). Relatively more patients in the high-intensity group were of non-Hispanic black ethnicity, were nursing home residents, or presented with congestive heart failure or oxygen desaturation; patients in the high-intensity group were less likely to have pleural effusion. The proportion of low-risk patients ranged from 53.1% in the high-intensity group to 65.0% in the moderate-intensity group.

Most of the 409 providers who enrolled patients were emergency medicine physicians (80.1%), men (79.7%), or of non-Hispanic white ethnicity (86.5%); no statistically significant differences in characteristics were present across intervention groups. Of the 32 emergency departments, 29 (90.6%) were urban in location and 16 (50.0%) were part of teaching hospitals. Although fewer sites in the high-intensity group (8.3%) had observation units and fewer in the low-intensity group used pneumonia order forms (12.5%), no statistically significant differences in site characteristics were observed across intervention groups (**Table 2**).

Effectiveness of the Interventions for the Recommended Site of Treatment

Low-risk patients in the moderate-intensity (61.0%) and high-intensity (61.9%) groups were significantly more likely to be treated as outpatients compared with those in the low-intensity (37.5%) group (**Table 3**). The adjusted odds for outpatient treatment of low-risk patients were significantly elevated in the high-intensity and moderate-intensity groups relative to the low-intensity group (**Figure 2**); there was no difference in the odds of outpatient treatment in the high-intensity and moderate-intensity groups.

Higher-risk patients in the moderate-intensity group were statistically significantly more likely to be treated as outpatients (9.6%) compared with those in the low-intensity (2.4%) and high-intensity (3.2%) groups (**Table 3**). The adjusted odds for outpatient treatment of higher-risk patients were significantly elevated in the moderate-intensity group relative to the low-intensity and high-intensity groups (**Figure 2**), whereas the odds in the high-intensity and low-intensity groups were not statistically significantly different.

Effectiveness of the Interventions for the Recommended Processes of Care

Arterial oxygenation was assessed in 94.8% (low-intensity group) to 96.7% (high-intensity group) of outpatients and in 96.3% (low-intensity group) to 99.1% (moderate-intensity group) of inpatients; there were no statistically significant differences by intervention group (**Table 4**). Outpatients in the high-intensity group were significantly more likely to receive the first dose of antibiotic therapy (high-intensity group, 90.9%; moderate-intensity group, 70.1%; low-intensity group, 64.9%) and guideline-compliant antibiotic therapy (high-intensity group, 65.6%; moderate-intensity group, 30.7%; low-intensity group, 29.3%) in the emergency department. Outpatients in the high-intensity group were also more likely to receive all 4 guideline-recommended processes of care (high-intensity group, 60.9%; moderate-intensity group, 28.3%; low-intensity group, 25.3%). More outpatients in the high-intensity and moderate-intensity groups were prescribed guideline-compliant antibiotic therapy at discharge from the emergency department (90.7% and 89.2%, respectively) than were outpatients in the low-intensity group (80.5%).

Relative to outpatients in the moderate-intensity or the low-intensity groups, the adjusted odds of outpatients in the high-intensity group receiving the first dose of antibiotic therapy in the emergency department, appropriate antibiotic therapy in the emergency department, and all 4 guideline-recommended processes of care were statistically significantly elevated (**Figure 2**). The adjusted odds of outpatients in the high-intensity and moderate-intensity groups receiving guideline-compliant antibiotic therapy at discharge from the emergency department were statistically significantly elevated relative to outpatients in the low-intensity group.

Inpatients in the high-intensity group were significantly more likely to have 2 blood cultures obtained before initiation of antibiotic therapy (high-intensity group,

Table 3. **Frequency of Outpatient Treatment for Low-Risk and Higher-Risk Patients by Intervention Group***

Risk Group†	Guideline Implementation Group			*P* Value‡
	Low Intensity, *n/n (%)*	Moderate Intensity, *n/n (%)*	High Intensity, *n/n (%)*	
Low-risk patients				
Class I	88/137 (64.2)	242/284 (85.2)	239/277 (86.3)	0.009
Class II	57/177 (32.2)	156/267 (58.4)	142/253 (56.1)	0.020
Class III	22/131 (16.8)	63/205 (30.7)	52/170 (30.6)	0.090
All low-risk patients	167/445 (37.5)	461/756 (61.0)	433/700 (61.9)	0.004
Higher-risk patients				
Classes I–III with oxygen desaturation	3/52 (5.8)	11/87 (12.6)	9/120 (7.5)	–
Class IV	3/191 (1.6)	27/244 (11.1)	8/389 (2.1)	–
Class V	1/52 (1.9)	1/75 (1.3)	3/108 (2.8)	–
All higher-risk patients	7/295 (2.4)	39/406 (9.6)	20/617 (3.2)	0.004

* Percentages are the subset treated as outpatients/the total number of patients in a given risk class who were treated in the emergency department.
† *Low-risk* denotes patients in risk classes I–III without clinically significant arterial oxygen desaturation at presentation, defined as PO_2 less than 60 mm Hg by blood gas analysis or oxygen saturation less than 90% by pulse oximetry.
‡ *P* values compare the proportion of patients within severity strata and across intervention groups who were treated as outpatients; all calculations account for the clustering of patients within providers and emergency departments. *P* values were not calculated for individual strata of higher-risk patients because of sparse data.

74.2%; moderate-intensity group, 57.6%; low-intensity group, 53.5%), to receive guideline-compliant antibiotic therapy (high-intensity group, 74.3%; moderate-intensity group, 59.6%; low-intensity group, 50.0%), and to receive all 4 guideline-recommended processes of care (high-intensity group, 44.3%; moderate-intensity group, 30.1%; low-intensity group, 23.0%) (**Table 4**). Antibiotic therapy was initiated within 4 hours of presentation in 77.0% (low-intensity group) to 79.7% (moderate-intensity group) of inpatients, and there was no statistically significant difference by intervention group. Relative to inpatients in the moderate-intensity and low-intensity groups, the adjusted odds of inpatients in the high-intensity group having 2 blood cultures obtained before initiation of antibiotic therapy, receiving guideline-compliant antibiotic therapy, and receiving all 4 guideline-recommended processes of care were statistically significantly elevated (**Figure 2**).

Safety of the Interventions

Differences in 30-day mortality for low-risk and higher-risk patients across all groups were not statistically significant (**Table 5**). The only death among low-risk outpatients was in a patient in risk class III in the moderate-intensity group who died 10 days after presentation during a subsequent hospitalization for myocardial infarction. No statistically significant between-group differences were observed in any of the other safety outcomes, either unadjusted (**Table 5**) or adjusted for state and PSI risk classes (**Figure 3**).

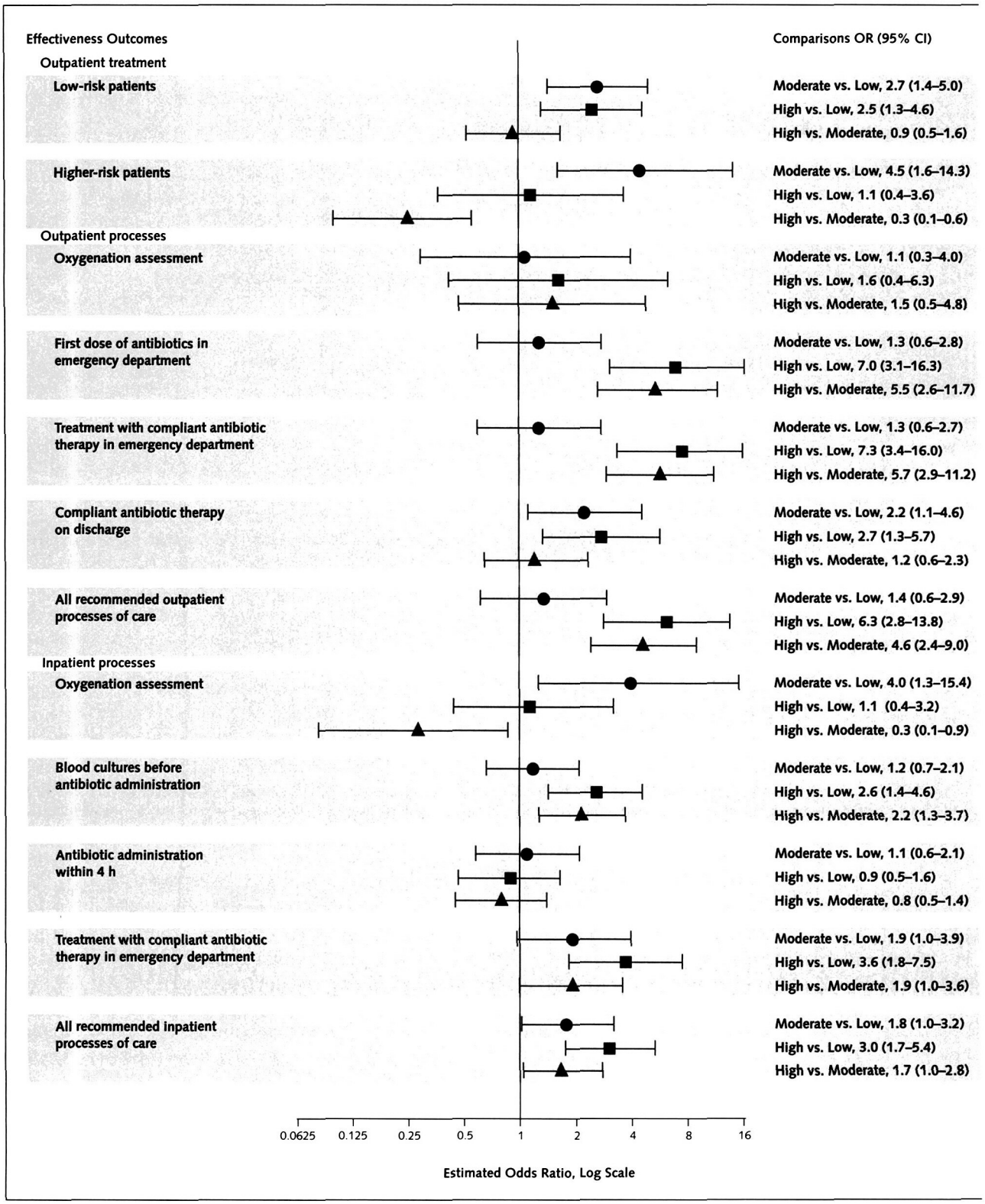
DISCUSSION

Several features of our trial distinguish it from previous studies to improve the efficiency or quality of care for pneumonia (5–9, 20–22). In contrast to the LOCAP (Low-Risk Community-Acquired Pneumonia) study (5) and CAPITAL (Community-Acquired Pneumonia Intervention Trial Assessing Levofloxacin) (6), we included higher-risk patients and explicitly incorporated the important prognostic finding of arterial oxygen desaturation into the site-of-treatment recommendations. Unlike LOCAP, CAPITAL, and a recently conducted trial (7), we allowed providers to select empirical therapy rather than restricting treatment to a single proprietary antibiotic. Our project guideline comprised processes of care that are broadly considered to be quality indicators for pneumonia (14–18). Finally, our comparison of 3 interventions in a multicenter trial allowed us to examine the incremental benefits of strategies of increasing intensity in a diverse set of patients, providers, and emergency departments.

Our findings demonstrate that both moderate-intensity and high-intensity guideline implementation strategies increased the proportion of low-risk patients who were treated on an outpatient basis. The observed absolute increases in outpatient treatment of 24.4% (high intensity vs. low intensity) and 23.5% (moderate intensity vs. low intensity) are somewhat larger than the 15% and 18% increases reported in the LOCAP (5) and CAPITAL (6) studies. The outpatient treatment rate in the low-intensity group (37.5%) in our study was lower than that seen in the earlier studies (42.0% [5] and 51.0% [6]), which may partially explain our larger treatment effects. The different admission rates in our study's low-intensity group and in the control group of CAPITAL may be the result of systematic variation in admission rates between hospitals in the United States and Canada (where CAPITAL was performed) or the exclusion of severely ill patients in CAPITAL (6).

Although the moderate-intensity and high-intensity interventions increased the rate of outpatient treatment of low-risk patients, the moderate-intensity intervention was associated with an increased rate of outpatient treatment (9.6%) for higher-risk patients compared with the low-intensity (2.4%) and high-intensity (3.2%) interventions.

Figure 2. **Adjusted pairwise comparisons of intervention groups for the effectiveness outcomes.**



The solid circles, squares, and triangles represent the adjusted odds ratios (*ORs*) for the effectiveness outcomes, and the corresponding bars represent the 95% CIs for these estimates. Pairwise comparisons of outpatient treatment by intervention group are made separately for low-risk and higher-risk patients, adjusting for state and severity of illness (risk class and arterial oxygen desaturation). Pairwise comparisons of the processes of care for outpatients and inpatients by intervention group are adjusted for state and severity of illness (low risk vs. higher risk) at presentation. An OR greater than 1.0 indicates a greater likelihood of outpatient treatment or having the recommended process of care performed. *Low* denotes low-intensity group, *Moderate* denotes moderate-intensity group, and *High* denotes high-intensity group.

Table 4. **Performances of Processes of Care by Intervention Group for Outpatients and Inpatients**

Process of Care	Guideline Implementation Group			*P* Value*
	Low Intensity	Moderate Intensity	High Intensity	
Outpatients				
Patients, *n*	174	498	453	
Oxygenation assessment at presentation, %†	94.8	95.6	96.7	0.83
First dose of antibiotic therapy in the emergency department, %	64.9	70.1	90.9	<0.001
Antibiotic therapy administered in the emergency department, %‡				<0.001
No antibiotic therapy	35.1	29.9	9.1	
Noncompliant therapy	17.8	20.7	3.8	
Partially compliant therapy	17.8	18.7	21.6	
Compliant therapy	29.3	30.7	65.6	
Antibiotic therapy prescribed at discharge from the emergency department, %‡				0.02
No antibiotic therapy	9.8	1.0	3.5	
Noncompliant therapy	7.5	7.0	3.8	
Partially compliant therapy	2.3	2.8	2.0	
Compliant therapy	80.5	89.2	90.7	
Recommended processes of care performed, %§				<0.001
0–1	9.2	4.8	2.0	
2	37.4	33.1	13.0	
3	28.2	33.7	24.1	
4	25.3	28.3	60.9	
Inpatients				
Patients, *n*	566	661	849	
Oxygenation assessment at presentation, %†	96.3	99.1	97.4	0.180
Performance of 2 blood cultures before antibiotic administration, %‖	53.5	57.6	74.2	0.001
Administration of antibiotic therapy within 4 h of presentation, %	77.0	79.7	78.8	0.82
Antibiotic therapy administered in the emergency department, %‡				0.002
No antibiotic therapy	8.3	5.9	3.7	
Noncompliant therapy	40.1	32.4	19.4	
Partially compliant therapy	1.6	2.1	2.6	
Compliant therapy	50.0	59.6	74.3	
Recommended processes of care performed, %§				<0.001
0–1	7.8	6.7	2.9	
2	30.0	20.6	13.5	
3	39.2	42.7	39.2	
4	23.0	30.1	44.3	

* *P* values compare the proportion of patients who are fully compliant with the recommended processes of care across intervention groups. *P* values for the number of processes of care performed for outpatients and inpatients were based on an ordinal scale. Analyses accounted for the clustering of patients within providers and emergency departments.

† Assessment of arterial oxygenation in the 1125 outpatients was performed by using pulse oximetry only in 91.7% and both pulse oximetry and arterial blood gas analysis in 4.2%. Assessment of arterial oxygenation in the 2076 inpatients was performed by using pulse oximetry only in 71.3%, arterial blood gas analysis only in 0.3%, and both pulse oximetry and arterial blood gas analysis in 26.0%.

‡ Noncompliant therapy denotes the prescription or administration of antibiotic agents that were not recommended by the project guideline. Partially compliant therapy denotes the prescription or administration of a guideline-recommended antibiotic agent by a nonrecommended route or the use of a guideline-recommended antibiotic agent coupled with the prescription or administration of 1 or more nonrecommended antibiotic agents. Compliant therapy denotes the prescription or administration of only the guideline-recommended antibiotic agents by the recommended route.

§ Each outpatient in this study received at least 1 of 4 guideline-recommended processes of care. None of the 4 guideline-recommended processes of care were performed for 3 (0.5%) inpatients in the low-intensity group, 1 (0.2%) inpatient in the moderate-intensity group, and 1 (0.1%) inpatient in the high-intensity group.

‖ The following significant ($P = 0.004$) differences by intervention group were observed for blood cultures obtained within 24 hours of presentation: 73.1% for the low-intensity group, 81.1% for the moderate-intensity group, and 91.6% for the high-intensity group.

Some patient circumstances alter the generally accepted clinical practice of admitting higher-risk patients, such as terminal conditions, do-not-resuscitate status, or strong patient or family preferences. In our study, we excluded patients who were terminally ill and those admitted only for palliative care, and we observed no differences in code status across treatment groups. The moderate-intensity intervention itself possibly contributed to this difference, and the high-intensity intervention may have more effectively conveyed the message that outpatient care is not recommended for higher-risk patients.

Nearly 40% of low-risk patients in the high-intensity group (14% of whom were in risk class I to 69% who were in risk class III) were treated on an inpatient basis, suggesting that physicians often use their clinical judgment to overrule objective risk stratification (15, 33–35). That clinicians overrode the guideline recommendation for outpatient therapy, particularly for patients in risk classes II and III, is consistent with previous studies (5, 6). Factors that probably prompted these decisions include 1) the medical and psychosocial contraindications to outpatient care that were explicitly incorporated into the study guideline and 2) the tendency for physicians to overestimate the severity of illness in low-risk patients who are older and have 1 or more comorbid conditions (23). Our trial further demonstrated that the high-intensity intervention was most effec-

tive at increasing the performance rates for many of the recommended processes of care. Although the high-intensity intervention led to large relative improvements in the overall performance of the 4 recommended processes of care, only 61% of outpatients and 44% of inpatients had all processes completed. This finding reinforces the need for more potent quality improvement strategies for patients with pneumonia.

More specifically, our study identified opportunities to improve the physician's approach to prescribing antibiotic therapy for pneumonia. Even in the high-intensity group, 34% of outpatients and 26% of inpatients did not receive antibiotic therapy in the emergency department that complied with guideline recommendations. Most commonly, physicians who did not comply with guidelines for outpatients were overusing multiple-agent regimens or administering therapy parenterally—more costly treatments that are unlikely to improve patient outcomes. Providers who did not comply with inpatient guidelines were most often prescribing antibiotic agents that were not recommended, a noteworthy finding given the association between appropriate empirical antibiotic therapy and improved survival for inpatients with this illness (11, 12).

The observed assessment of arterial oxygenation in nearly all outpatients (>95%) and inpatients (>97%) probably reflects a "ceiling effect." Other large studies have documented performance rates of 89% to 95% for assessment of oxygenation, suggesting that quality improvement initiatives are unlikely to make further improvements in this measure at most hospitals (9, 30). The lack of an

Table 5. **Safety Outcomes for Low-Risk and Higher-Risk Patient Subgroups by Intervention Group**

Outcome	Guideline Implementation Group			*P* Value*
	Low Intensity	Moderate Intensity	High Intensity	
All low-risk patients†				
Patients, *n*	445	756	700	
Death within 30 days, %				
Class I	0.0	0.0	0.0	–
Class II	1.2	1.1	1.6	–
Class III	6.2	2.9	3.6	–
All low-risk patients	2.3	1.2	1.5	0.47
Median days to return to work and usual activities (interquartile range), *n*				
Return to work	10 (6 to 21)	9 (5 to 21)	9 (5 to 17)	0.42
Return to usual activities for nonworkers	17.5 (8 to >29)	19 (7 to >29)	15 (7 to >29)	0.41
Return to usual activities for workers	15 (7.5 to 28.5)	14 (7 to >29)	14 (7 to 28)	0.16
Patient satisfaction with care, %				
"Satisfied" with site-of-treatment decision	90.0	87.0	86.9	0.36
"Very satisfied" with emergency department care	71.1	66.0	66.3	0.36
"Very satisfied" with overall medical care	66.9	70.3	69.0	0.62
Low-risk outpatients‡				
Patients, *n*	167	461	433	
Subsequent hospitalization, %	6.6	6.1	5.8	0.99
Low-risk inpatients‡				
Patients, *n*	278	295	267	
Any medical complication, %	26.9	22.9	19.5	0.16
Pneumonia-related medical complication, %§	16.7	11.0	11.5	0.10
Admission to intensive care unit, %	6.5	6.8	10.7	0.17
Higher-risk patients‖				
Patients, *n*	295	406	617	
Death within 30 days, %				
Class I–III with oxygen desaturation¶	1.9	2.3	0.8	–
Class IV	4.7	8.6	9.0	–
Class V	28.8	17.3	19.4	–
All higher-risk patients	8.5	8.9	9.3	0.92

* *P* values compare the outcomes of various patient subgroups across intervention groups; all calculations account for the clustering of patients within providers and emergency departments. *P* values were not calculated for individual risk strata because of sparse data.

† Low-risk patients were in risk classes I through III without evidence of clinically significant arterial oxygen desaturation. Follow-up to assess 30-day mortality was incomplete for 53 (2.8%) low-risk patients (low-intensity group, 7 patients; moderate-intensity group, 21 patients; high-intensity group, 25 patients). Follow-up interviews to assess return to work and usual activities and satisfaction with care were incomplete for an additional 173 (9.1%) low-risk patients (low-intensity group, 34 patients; moderate-intensity group, 73 patients; high-intensity group, 66 patients) known to be alive at 30 days. Patients with incomplete follow-up were excluded from the denominator in the calculation of these outcomes measures.

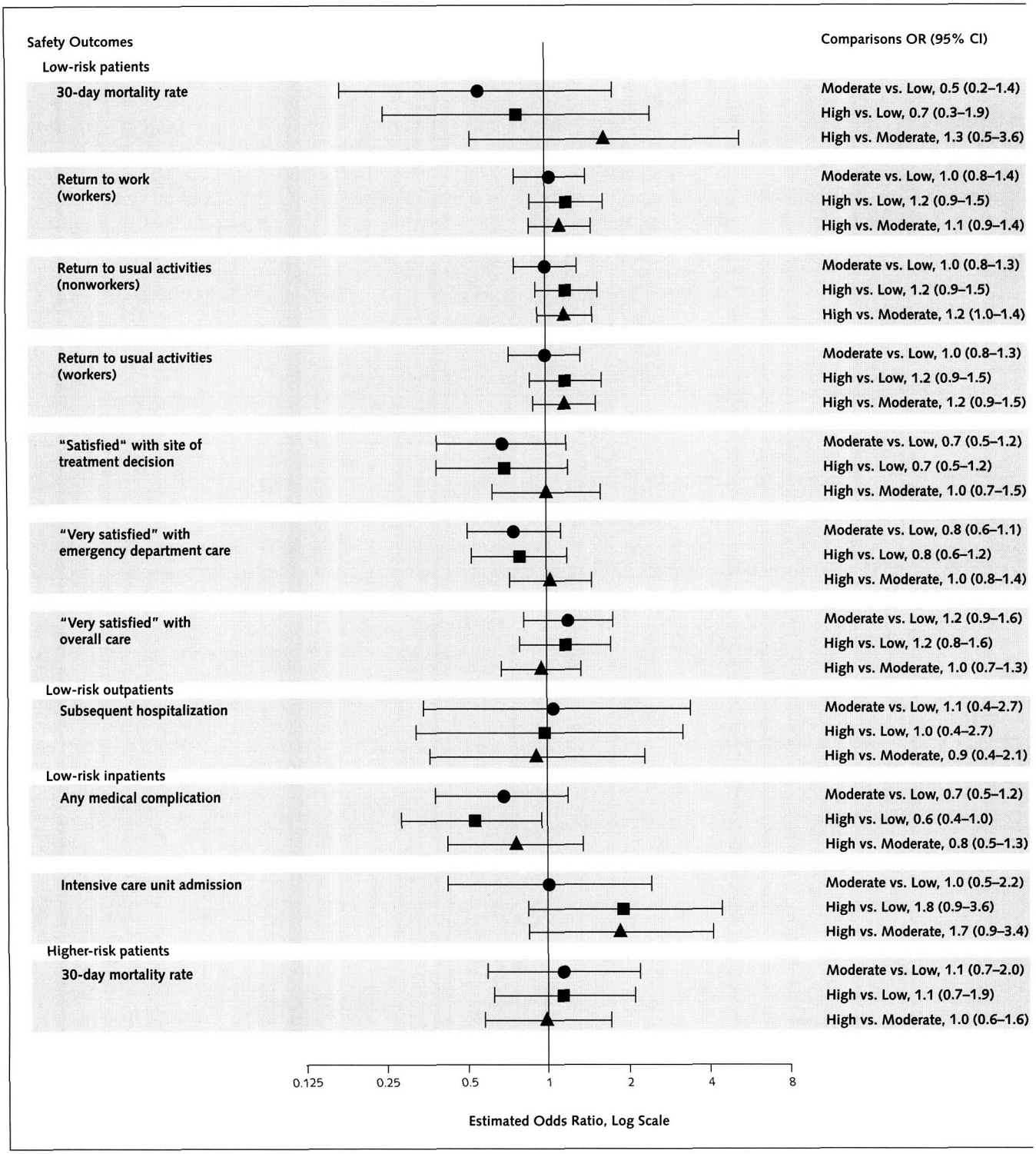
‡ Medical record review to assess subsequent hospitalization was incomplete for 2 low-risk outpatients. Medical record review to assess medical complications was incomplete for 12 low-risk inpatients, and record review to assess admissions to intensive care units was incomplete for 8 low-risk inpatients. Patients without medical record reviews were excluded from the denominator in the calculation of these outcomes measures.

§ A pneumonia-related complication was defined as respiratory failure, new or worsening heart failure or pulmonary edema, atrial arrhythmia, evidence of suppurative infection, or sepsis (12).

‖ Follow-up to assess 30-day mortality was incomplete for 3 higher-risk patients, who were excluded from the denominator in the analysis of this outcome.

¶ Clinically significant arterial oxygen desaturation was defined as PO_2 less than 60 mm Hg by blood gas analysis or oxygen saturation less than 90% by pulse oximetry.

Figure 3. **Adjusted pairwise comparisons of intervention groups for safety outcomes.**



The solid circles, squares, and triangles represent the adjusted odds ratios (*ORs*) for the safety outcomes, and the corresponding bars represent the 95% CIs for these estimates. Pairwise comparisons of these outcomes by intervention group are made separately for relevant subgroups of patients, adjusting for state and severity of illness. An OR greater than 1.0 indicates a greater likelihood of a given outcome. *Low* denotes low-intensity group, *Moderate* denotes moderate-intensity group, and *High* denotes high-intensity group.

intervention effect for the timeliness of initiating inpatient antibiotic therapy may also be attributable to the relatively high (80%) compliance rate for this process measure across all 3 intervention groups; in comparison, a compliance rate of 61% was observed in a recent national study of 13 771 elderly inpatients with pneumonia (10). The higher rate

that we observed may also reflect that all patients were admitted through the emergency department, where it is more feasible to rapidly initiate antibiotic therapy following the admission decision.

Use of our guideline did not appear to compromise patient safety. Despite the higher rate of outpatient treatment among low-risk (moderate-intensity and high-intensity groups) and higher-risk (moderate-intensity group) patients, we observed no differences in mortality rates across intervention groups. Furthermore, guideline implementation did not negatively influence other outcomes that are important to patients, such as the need for subsequent hospitalization, the speed at which they are able to return to work or usual activities, or their satisfaction with care.

Six limitations of our trial should be acknowledged. First, demographic characteristics differed between eligible patients who were and were not enrolled. However, our 71% enrollment rate is laudable for a multicenter clinical trial, and the enrolled patients were demographically and clinically diverse. Second, we observed a lower enrollment rate and higher rate of exclusion following enrollment in the low-intensity group relative to the other groups. Nevertheless, the similarity of enrolled patients across all 3 groups supports the internal validity of the study comparisons. Third, randomization at the emergency department level does not ensure balance at the patient or provider level. We observed some imbalances in levels of illness severity across the intervention groups; however, our analyses of the site of treatment were performed separately for low-risk and higher-risk patients, and our multivariable analyses were not sensitive to the few imbalances that were observed at baseline. Fourth, we did not collect information on the use of patient medical resources or the costs of guideline implementation; therefore, we cannot quantify the relative cost-effectiveness of our 3 interventions. Fifth, we did not incorporate a true usual-care control group, which may have led us to underestimate the true magnitude of effect of the moderate-intensity and high-intensity interventions. Sixth, we did not collect pretrial or post-trial data on the site of treatment or the processes of care for patients who met our eligibility criteria. Therefore, we can neither exclude the possibility of baseline institutional differences nor assess the persistence of the intervention effects after the intervention has been discontinued.

In conclusion, we found that emergency departments that used moderate-intensity and high-intensity guidelines safely increased the proportion of low-risk patients with pneumonia who were treated as outpatients. The high-intensity strategy was most effective in increasing the performance of recommended processes of care for outpatients and inpatients alike, and it was more effective than the moderate-intensity strategy for conveying that inpatient treatment is recommended for higher-risk patients.

From University of Pittsburgh and the Veterans Affairs Center for Health Equity Research and Promotion, Pittsburgh, Pennsylvania; Qualidigm, Middletown, Connecticut; Yale University School of Medicine, New Haven, Connecticut; New Britain General Hospital, New Britain, Connecticut; Norwalk Hospital, Norwalk, Connecticut; University of Connecticut, Storrs, Connecticut; and Clement J. Zablocki Veterans Administration Medical Center and Medical College of Wisconsin, Milwaukee, Wisconsin.

Grant Support: By the Agency for Healthcare Research and Quality (grant number R01 HS10049). Dr. M.J. Fine received support from the National Institute of Allergy and Infectious Diseases (grant number K24 AI001769).

Potential Financial Conflicts of Interest: *Consultancies:* M.J. Fine (University of Pennsylvania, GeneSoft Pharmaceuticals Inc.); *Honoraria:* M.J. Fine (Zynx Health Corporation, STA Healthcare Communications Inc., University of Alberta, Maine Medical Center); *Expert testimony:* M.J. Fine (Stephen Lynn Klein, Kellogg & Siegelman, Swanson, Martin, & Bell, William J. Burke, Chad McGowan, Chernett, Wasserman, Yarger, Pasternak, LLC); *Grants received:* M.J. Fine (Pfizer Inc.); *Royalties:* M.J. Fine (Up-to-Date).

Requests for Single Reprints: Michael J. Fine, MD, MSc, Veterans Administration Pittsburgh Healthcare System (151-C-U), Center for Health Equity Research and Promotion, University Drive C, Building 28, 1A102, Pittsburgh, PA 15240; e-mail, Michael.Fine@va.gov.

Current author addresses are available at www.annals.org.

References

1. **Fine MJ, Hough LJ, Medsger AR, Li YH, Ricci EM, Singer DE, et al.** The hospital admission decision for patients with community-acquired pneumonia. Results from the pneumonia Patient Outcomes Research Team cohort study. Arch Intern Med. 1997;157:36-44. [PMID: 8996039]

2. **Coley CM, Li YH, Medsger AR, Marrie TJ, Fine MJ, Kapoor WN, et al.** Preferences for home vs hospital care among low-risk patients with community-acquired pneumonia. Arch Intern Med. 1996;156:1565-71. [PMID: 8687265]

3. **Lave JR, Lin CCJ, Fine MJ, Hughes-Cromwick P.** The cost of treating patients with community-acquired pneumonia. Sem Respir Crit Care Med. 1999;20:189-97.

4. **Fine MJ, Auble TE, Yealy DM, Hanusa BH, Weissfeld LA, Singer DE, et al.** A prediction rule to identify low-risk patients with community-acquired pneumonia. N Engl J Med. 1997;336:243-50. [PMID: 8995086]

5. **Atlas SJ, Benzer TI, Borowsky LH, Chang Y, Burnham DC, Metlay JP, et al.** Safely increasing the proportion of patients with community-acquired pneumonia treated as outpatients: an interventional trial. Arch Intern Med. 1998;158:1350-6. [PMID: 9645830]

6. **Marrie TJ, Lau CY, Wheeler SL, Wong CJ, Vandervoort MK, Feagan BG.** A controlled trial of a critical pathway for treatment of community-acquired pneumonia. CAPITAL Study Investigators. Community-Acquired Pneumonia Intervention Trial Assessing Levofloxacin. JAMA. 2000;283:749-55. [PMID: 10683053]

7. **Carratala J, Fernandez-Sabe N, Ortega L, Castellsague X, Roson B, Dorca J, et al.** Outpatient care compared with hospitalization for community-acquired pneumonia: a randomized trial in low-risk patients. Ann Intern Med. 2005;142:165-72. [PMID: 15684204]

8. **McGarvey RN, Harper JJ.** Pneumonia mortality reduction and quality improvement in a community hospital. QRB Qual Rev Bull. 1993;19:124-30. [PMID: 8493027]

9. **Meehan TP, Fine MJ, Krumholz HM, Scinto JD, Galusha DH, Mockalis JT, et al.** Quality of care, process, and outcomes in elderly patients with pneumonia. JAMA. 1997;278:2080-4. [PMID: 9403422]

10. **Houck PM, Bratzler DW, Nsa W, Ma A, Bartlett JG.** Timing of antibiotic administration and outcomes for Medicare patients hospitalized with community-acquired pneumonia. Arch Intern Med. 2004;164:637-44. [PMID: 15037492]

11. **Houck PM, MacLehose RF, Niederman MS, Lowery JK.** Empiric antibiotic therapy and mortality among Medicare pneumonia inpatients in 10 western states: 1993, 1995, and 1997. Chest. 2001;119:1420-6. [PMID: 11348948]
12. **Gleason PP, Meehan TP, Fine JM, Galusha DH, Fine MJ.** Associations between initial antimicrobial therapy and medical outcomes for hospitalized elderly patients with pneumonia. Arch Intern Med. 1999;159:2562-72. [PMID: 10573046]
13. **Levin KP, Hanusa BH, Rotondi A, Singer DE, Coley CM, Marrie TJ, et al.** Arterial blood gas and pulse oximetry in initial management of patients with community-acquired pneumonia. J Gen Intern Med. 2001;16:590-8. [PMID: 11556939]
14. **Niederman MS, Mandell LA, Anzueto A, Bass JB, Broughton WA, Campbell GD, et al.** Guidelines for the management of adults with community-acquired pneumonia. Diagnosis, assessment of severity, antimicrobial therapy, and prevention. Am J Respir Crit Care Med. 2001;163:1730-54. [PMID: 11401897]
15. **Mandell LA, Bartlett JG, Dowell SF, File TM Jr, Musher DM, Whitney C.** Update of practice guidelines for the management of community-acquired pneumonia in immunocompetent adults. Clin Infect Dis. 2003;37:1405-33. [PMID: 14614663]
16. **Mandell LA, Marrie TJ, Grossman RF, Chow AW, Hyland RH.** Canadian guidelines for the initial management of community-acquired pneumonia: an evidence-based update by the Canadian Infectious Diseases Society and the Canadian Thoracic Society. The Canadian Community-Acquired Pneumonia Working Group. Clin Infect Dis. 2000;31:383-421. [PMID: 10987698]
17. **Centers for Medicare & Medicaid Services.** National Pneumonia Medicare Quality Improvement Project: Pneumonia Collaborative Framework. Accessed at www.medqic.org/dcs/ContentServer?cid=1116947498569&pagename=Medqic%2FMQTools%2FToolTemplate&c=MQTools on 30 June 2005.
18. **Joint Commission on Accreditation of Healthcare Organizations.** Overview of the community-acquired pneumonia (CAP) core measure set (3/22/02). Accessed at www.jcaho.org/pms/core+measures/cap_overview.htm on 30 June 2005.
19. **McGlynn EA, Asch SM, Adams J, Keesey J, Hicks J, DeCristofaro A, et al.** The quality of health care delivered to adults in the United States. N Engl J Med. 2003;348:2635-45. [PMID: 12826639]
20. **Chu LA, Bratzler DW, Lewis RJ, Murray C, Moore L, Shook C, et al.** Improving the quality of care for patients with pneumonia in very small hospitals. Arch Intern Med. 2003;163:326-32. [PMID: 12578513]
21. **Suchyta MR, Dean NC, Narus S, Hadlock CJ.** Effects of a practice guideline for community-acquired pneumonia in an outpatient setting. Am J Med. 2001; 110:306-9. [PMID: 11239849]
22. **Halm EA, Horowitz C, Silver A, Fein A, Dlugacz YD, Hirsch B, et al.** Limited impact of a multicenter intervention to improve the quality and efficiency of pneumonia care. Chest. 2004;126:100-7. [PMID: 15249449]
23. **Yealy DM, Auble TE, Stone RA, Lave JR, Meehan TP, Graff LG, et al.** The emergency department community-acquired pneumonia trial: methodology of a quality improvement intervention. Ann Emerg Med. 2004;43:770-82. [PMID: 15159711]
24. **Davis DA, Taylor-Vaisey A.** Translating guidelines into practice. A systematic review of theoretic concepts, practical experience and research evidence in the adoption of clinical practice guidelines. CMAJ. 1997;157:408-16. [PMID: 9275952]
25. **Bero LA, Grilli R, Grimshaw JM, Harvey E, Oxman AD, Thomson MA.** Closing the gap between research and practice: an overview of systematic reviews of interventions to promote the implementation of research findings. The Cochrane Effective Practice and Organization of Care Review Group. BMJ. 1998;317:465-8. [PMID: 9703533]
26. **Berwick DM.** Developing and testing changes in delivery of care. Ann Intern Med. 1998;128:651-6. [PMID: 9537939]
27. **Murrey KO, Gottlieb LK, Schoenbaum SC.** Implementing clinical guidelines: a quality management approach to reminder systems. QRB Qual Rev Bull. 1992;18:423-33. [PMID: 1287524]
28. **Thomson O'Brien MA, Oxman AD, Davis DA, Haynes RB, Freemantle N, Harvey EL.** Audit and feedback: effects on professional practice and health care outcomes. Cochrane Database Syst Rev. 2000:CD000259. [PMID: 10796520]
29. **Donner A, Klar N.** Pitfalls of and controversies in cluster randomization trials. Am J Public Health. 2004;94:416-22. [PMID: 14998805]
30. **Dedier J, Singer DE, Chang Y, Moore M, Atlas SJ.** Processes of care, illness severity, and outcomes in the management of community-acquired pneumonia at academic hospitals. Arch Intern Med. 2001;161:2099-104. [PMID: 11570938]
31. **Rice N.** Binomial Regression. In: Leyland AH, Goldstein H, eds. Multilevel Modelling of Health Statistics. Hoboken, NJ: J Wiley; 2001:27-43.
32. **Browne WJ.** MCMC Estimation in MLwiN, version 2.0. London: Univ of London; 2003.
33. **Metlay JP, Fine MJ.** Testing strategies in the initial management of patients with community-acquired pneumonia. Ann Intern Med. 2003;138:109-18. [PMID: 12529093]
34. **Halm EA, Teirstein AS.** Clinical practice. Management of community-acquired pneumonia. N Engl J Med. 2002;347:2039-45. [PMID: 12490686]
35. **Bartlett JG, Dowell SF, Mandell LA, File TM Jr, Musher DM, Fine MJ.** Practice guidelines for the management of community-acquired pneumonia in adults. Infectious Diseases Society of America. Clin Infect Dis. 2000;31:347-82. [PMID: 10987697]