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Early Bronchoalveolar Lavage for Intubated Trauma Patients with TBI or Chest Trauma

Tyler J. Loftus, MD, Stephen J. Lemon, PharmD, Linda L. Nguyen, BS, Stacy A. Voils, PharmD, Scott C. Brakenridge, MD, MSCS, Janeen R. Jordan, MD, FACS, Chasen A. Croft, MD, FACS, R. Stephen Smith, MD, FACS, Frederick A. Moore, MD, FACS, MCCM, Philip A. Efron, MD, FACS, FCCM, and Alicia M. Mohr, MD, FACS, FCCM

Department of Surgery and Center for Sepsis and Critical Illness Research, University of Florida College of Medicine, Gainesville, Florida 32610

Abstract

Purpose—To evaluate the efficacy of an early bronchoalveolar lavage (E-BAL) protocol. BAL was performed within 48h for intubated patients with traumatic brain injury or chest trauma. We hypothesized that E-BAL would decrease antibiotic use and improve outcomes compared to late BAL (L-BAL) triggered by clinical signs of pneumonia.

Methods—Retrospective cohort analysis of 132 patients with quantitative BAL and 1 risk factor: head Abbreviated Injury Score ≥ 2 , ≥ 3 rib fractures, or radiographic signs of aspiration or pulmonary contusion. E-BAL (n=71) was compared to L-BAL (n=61). Pneumonia was defined as 10^4 organisms on BAL or Clinical Pulmonary Infection Score >6 .

Results—There were no significant differences in age, injury severity, initial PaO₂:FiO₂, or smoking status between E-BAL and L-BAL groups. 52% and 61% of the E-BAL and L-BAL cultures were positive, respectively. E-BAL patients had fewer antibiotic days (7.3 vs. 9.2, $p=0.034$), ventilator days (11 vs. 15, $p=0.002$), tracheostomies (49% vs. 75%, $p=0.002$), and shorter intensive care unit and hospital length of stay (13 vs. 17 days ($p=0.007$), 18 vs. 22 days ($p=0.041$)).

Conclusions—More than half of all E-BAL patients had pneumonia present early after admission. E-BAL was associated with fewer days on antibiotics and better outcomes than L-BAL.

Keywords

trauma; aspiration; pneumonia; antibiotics; bronchoalveolar lavage; clinical pulmonary infection score

Please address correspondence to: Alicia M. Mohr, MD, FACS, FCCM, University of Florida, Department of Surgery, 1600 SW Archer Road, Box 100108, Gainesville, FL 32610, Tel: (352) 273-5670, Fax: (352) 273-5683, alicia.mohr@surgery.ufl.edu.

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Introduction

Patients with traumatic brain injury (TBI) or chest trauma are at increased risk for aspiration and pneumonia [1–3]. Aspiration events occur in about two out of three patients with severe TBI and are more likely to cause pneumonia if there is a large burden of microorganisms, a particularly virulent organism, or impaired host defenses [4, 5]. Pneumonia occurs in one out of five young trauma patients with 3–4 rib fractures, almost one third of geriatric (age ≥ 65) patients with 3–4 rib fractures, and over half of all geriatric patients with more than six rib fractures [6]. Two factors contribute to these findings: chest wall pain (which may inhibit voluntary pulmonary function and hinder the process of weaning from mechanical ventilation) and underlying pulmonary contusion. Pulmonary contusion occurs in about 17% of multi-trauma patients, and roughly one out of three will develop pneumonia [7, 8]. Pulmonary contusion, an injury to the lung parenchyma, is characterized by increased capillary permeability, epithelial and endothelial injury, bleeding into the lung parenchyma, pulmonary edema, and inflammation, providing a suitable microenvironment for infection [9, 10]. Alone or in combination, these injury patterns place trauma patients at increased risk for pneumonia.

Accurately diagnosing pneumonia among critically ill patients is difficult. The Clinical Pulmonary Infection Score (CPIS) developed by Pugin et al. [11] considers fever, leukocytosis, oxygenation, the character of tracheal secretions, and chest radiograph findings to diagnose pneumonia, and appears to perform as well as any other clinical criteria. However, the specificity of CPIS may be as low as 47% among medical and surgical intensive care unit (ICU) patients, promoting administration of unnecessary antibiotics [12]. Also, the sensitivity of CPIS is 72–77%, such that withholding antibiotics based on clinical criteria will undertreat a significant number of patients, placing them at increased risk for mortality [13–15]. Among critically ill trauma patients, clinical diagnosis of pneumonia is further complicated by the frequency of fever, leukocytosis, and abnormal chest radiographs in this population. Unfortunately, non-invasive diagnostic tools are also flawed. The upper respiratory tract is frequently colonized with bacteria within hours of intubation, and sampling of the lower airways with quantitative bronchoalveolar lavage (BAL) has only about 73% sensitivity and 82% specificity for diagnosing ventilator-associated pneumonia (VAP) among critically ill medical and surgical patients [3, 16]. In the absence of a pragmatic gold standard test, clinicians employ imperfect clinical and microbiologic criteria in making important management decisions for critically ill trauma patients. Notably, indiscriminate antibiotic use promotes development of multi-drug resistant organisms [17–19] increases the incidence of *Clostridium difficile* infections [20] and increases healthcare costs [21, 22].

In order to assess the frequency of post-injury aspiration, remove blood and debris from the airways, and guide antibiotic therapy, we instituted a protocol to perform fiberoptic bronchoscopy (FOB) and quantitative BAL within 48 hours following admission for all mechanically ventilated patients with TBI or chest trauma, termed early BAL (E-BAL). The purposes of this study were to describe gross and microbiologic findings on E-BAL, determine the effects E-BAL on antibiotic utilization, and establish associations between E-BAL findings and clinical outcomes. We hypothesized that early BAL would decrease

antibiotic use and improve outcomes compared to historic controls that underwent BAL after developing clinical signs of pneumonia.

Methods

Institutional Review Board approval was obtained for this database review. On November 1st, 2013 the Division of Acute Care Surgery at the University of Florida instituted an E-BAL protocol in which patients underwent FOB with quantitative BAL within 48 hours following admission if they had at least one of the following risk factors for pneumonia: head Abbreviated Injury Score $\geq$ two [23], the presence of three or more rib fractures, computed tomography (CT) scan evidence of aspiration, or CT evidence of pulmonary contusion. This study compared patients who underwent E-BAL to historic controls who would have qualified for the protocol, but instead underwent late BAL (L-BAL) more than 48 hours after admission based on clinical suspicion for pneumonia. Subjects were identified by retrospectively searching our institutional database for all consecutive trauma patients age $\geq$ 18 who had $\geq$ 48 hours of mechanical ventilation during admission and underwent FOB with quantitative BAL from May 1st, 2011 through May 1st, 2014, incorporating roughly equal populations before and after protocol initiation. Patients were included in the study group only if they had at least one of the risk factors for pneumonia incorporated in our E-BAL protocol (head Abbreviated Injury Score $\geq$ two, the presence of three or more rib fractures, computed tomography (CT) scan evidence of aspiration, or CT evidence of pulmonary contusion). Patients with any infection other than pneumonia or bacteremia were excluded in order to ensure that antibiotic administration patterns were not influenced by other conditions. Patients who received two or more doses of empiric antibiotics prior to BAL were also excluded to ensure that cultures were obtained at the time of diagnosis or clinical suspicion for all cases. For each patient, the interval between admission, intubation, and BAL were recorded. These parameters were compared between E-BAL and L-BAL groups. Empiric antibiotic choice was at the discretion of the primary team. There were no formal directives to change empiric antibiotic prescription practice patterns during the study period. However, our institutional practice is to forego coverage of methicillin-resistant *Staphylococcus aureus* and *Pseudomonas* species unless the patient is at increased risk for healthcare-associated and/or opportunistic infection. Transferred patients with outside hospital length of stay $\geq$ 24 hours were also excluded.

Fiberoptic bronchoscopy (FOB) and quantitative BAL were performed for all patients according to methodology summarized in the Memphis International Consensus report [24]. FOB is a standardized procedure in our trauma ICU. Proceduralists for BALs must demonstrate competency for the procedure, as delineated below, prior to being allowed to perform the procedure independently. For patients with no infiltrate on chest radiograph and no purulent secretions visualized during bronchoscopy, BAL was performed in the primary bronchi bilaterally, taking care to ensure that the posterior portion of the right lower lobe was sampled. The bronchoscope was advanced until wedged in a subsegmental bronchus at the desired location. The suction channel was flushed with 40–50 ml of non-bacteriostatic saline prior to infusing 80–100 ml of non-bacteriostatic saline and applying gentle suction (50–80 mmHg) to collect the lavage specimen in the collection trap.

Patients were grouped by interval between admission and their first BAL. Subsequent BALs were included in the analysis of recurrent pneumonia. A VAP prevention protocol was enacted before the beginning of the study period (May 1st, 2011). This protocol included head of bed elevation to 30 degrees, daily sedation holidays, universal peptic ulcer prophylaxis, daily oral hygiene with chlorhexidine mouth wash, and daily spontaneous breathing trials. Endotracheal tubes capable of clearing subglottic secretions were used for the duration of the study.

CT evidence of pulmonary contusion, rib fracture and aspiration were interpreted by a board certified attending radiologist from scans performed on the day of admission. The Abbreviated Injury Scale employed during the study period was revised in 2005 and updated in 2008 [23]. The incidence of diabetes mellitus was determined by ICD-9 diagnostic code review as well as medication reconciliation evidence of outpatient oral hypoglycemic or subcutaneous insulin use. Immunosuppression was defined as medication reconciliation evidence of outpatient or inpatient chemotherapy, high dose steroids (> 30 mg prednisone equivalent per day [25]), or the presence of an active disease that suppresses resistance to infection (e.g. leukemia, lymphoma, or Acquired Immune Deficiency Syndrome). Smoking status was obtained from the social history portion of the admission history and physical exam note and medication reconciliation evidence of outpatient or inpatient nicotine replacement therapy. Bloodstream infection was defined as 2/4 bottles positive for likely contaminants (e.g. coagulase negative *Staphylococcus epidermidis*, *Propionibacterium acnes*, and *Corynebacterium* species) or 1/4 bottles positive for other organisms. Secretions described as both thick and discolored in electronic medical record were considered purulent. Pre-culture antibiotics were defined as any systemic antibiotic therapy within the 72 window preceding BAL, based previous work demonstrating that antibiotic administration within window may affect the diagnostic yield of culture results [26]. CPIS was calculated as described by Pugin et al [11]. Gross findings on BAL were obtained from the procedure note, which is formatted with text fields to ensure that the author includes a description of findings. Gram stains with 2+ organisms were considered positive. Cultures with 10⁴ colony forming units/ml were considered positive. In clinical practice, a threshold of > 10⁵ CFU/ml avoids overtreatment of colonizing organism by limiting false positive results while maintaining a low rate of false negative results in trauma patients [27–29]. In this study, the < 10⁴ CFU/ml threshold was chosen to accurately identify true negative cultures and ensure appropriate classification of *Pseudomonas* and *Acinetobacter* species [27]. Multidrug resistance was defined as non-susceptibility to at least one agent in three or more antimicrobial categories [30]. Pneumonia was defined as CPIS > 6 or quantitative BAL with 10⁴ organisms. CPIS > 6 was included as a diagnostic criterion because BAL has approximately 73% sensitivity for the diagnosis of pneumonia among critically ill medical and surgical patients, and may therefore underrepresent patients with pneumonia [3]. Although the CPIS has several weaknesses, particularly in application to trauma patients, it does appear be as useful as any clinical scoring system in capturing patients with a false-negative BAL [12–15]. Recurrent pneumonia was defined as a new episode with CPIS > 6 or quantitative BAL with 10⁴ organisms occurring after a 72 hour period off antibiotics while not meeting criteria for the systemic inflammatory response syndrome [31] and occurring during the index admission or within thirty days of the original antibiotic stop date.

Statistical analysis was performed using SPSS version 23 (IBM, Armonk, NY). E-BAL and L-BAL groups were compared by Fisher's Exact test for discrete variables and one-way analysis of variance for continuous variables. Risk factors and predictors were identified by including significant bivariate predictors of the outcome variable and excluding independent variables with collinearity ($|r| \geq 0.2$ and $p < 0.05$) to other independent variables. Selected variables were entered into a multiple logistic regression equation. Confidence intervals were set at 95%, α was set at 0.05, and data were reported as mean (95% confidence interval) or n (%).

Results

Table 1 lists patient demographic information and risk factors for pneumonia. E-BAL and L-BAL groups were similar in terms of age, injury severity, and protocol inclusion criteria. Head AIS was higher among L-BAL patients, and there were a greater proportion of active smokers in the E-BAL cohort, but neither of these associations reached statistical significance. Factors which may influence culture results, such as gastric ulcer prophylaxis and pre-culture antibiotic, use were also similar between groups (Table 1).

Table 2 lists diagnostic findings in the study population. E-BAL and L-BAL groups had similarly short intervals between admission and intubation, whereas the interval between intubation and BAL was significantly longer among L-BAL patients (5.5 vs. 1.0 days, $p < 0.001$). At the time of BAL, CPIS was higher in the L-BAL group, though the proportion of patients with CPIS > 6 was similar between E-BAL and L-BAL groups (27% vs. 36%, respectively). 52% of all E-BAL patients and 61% of all L-BAL patients had pneumonia per BAL culture ($> 10^4$ colony forming units/ml), and this difference was not statistically significant. E-BAL patients were more likely to have fresh or clotted blood visualized in the airways during FOB and BAL. L-BAL patients were more likely to have a gram negative organism on culture, and had a higher incidence of polymicrobial cultures. Multidrug-resistant organisms were isolated from three patients, all from the E-BAL group (5% vs. 0%, $p = 0.096$). Each organism was resistant to penicillin and cephalosporin classes, with variable resistance to aminoglycosides and trimethoprim/sulfamethoxazole.

Although overall rates of pneumonia and recurrent pneumonia were similar between groups, the mean number of days on antibiotic therapy was lower in the E-BAL group (7.3 days vs. 9.2 days, $p = 0.034$). This was primarily attributable to lower rates of early antibiotic utilization in the E-BAL group, especially in the 3–5 day range (Figure 1). This difference did not appear to be influenced by the prevalence of antibiotic administration prior to obtaining cultures, which was similar between E-BAL and L-BAL patients (24% vs. 28%, $p = 0.607$). Also, the percentage of patients who received at least one day of antibiotics was nearly identical between E-BAL and L-BAL groups, as illustrated in Figure 1 (96% vs. 97%, $p > 0.999$). There were two patients in the E-BAL group who had antibiotics discontinued within five days and went on to have positive BAL cultures, and no such patients in the L-BAL group (2.8% vs. 0%, $p = 0.499$). E-BAL patients also had fewer days on mechanical ventilation, shorter ICU length of stay, and shorter hospital length of stay (Figure 2). However, these parameters were similar between groups when subtracting the interval between intubation and BAL for each group. Although the timing of tracheostomy was

similar between E-BAL and L-BAL groups (8.4 vs. 7.6 days, $p = 0.449$), E-BAL patients underwent fewer tracheostomy procedures (49% vs. 75%, $p = 0.002$). There were no significant differences between E-BAL and L-BAL groups for total hospital charges during admission (\$255,163 vs. \$297,785, $p = 0.108$), room charges (\$55,905 vs. 64,318, $p = 0.163$), or ancillary charges (\$199,257 vs. \$233,468, $p = 0.118$).

CPIS > 6 was the strongest predictor of having 10^4 colony forming units/ml on BAL culture, followed by gross purulence visualized at the time of FOB (Table 3). However, the accuracy of this model was mediocre (area under the receiver operating characteristic curve (AUROC) 0.69 (95% CI 0.59–0.78)). Factors which did not correlate with a positive BAL culture ($|r| < 0.2$) included temperature, white blood cell count, and the presence of a localized CXR infiltrate at the time of culture. The strongest predictor of recurrent pneumonia was the presence of *Enterobacter* in the BAL culture. Two (12%) *Enterobacter* isolates were multidrug-resistant, and seven (41%) were part of a polymicrobial culture. Together, the presence of an *Enterobacter* isolate and ICU LOS composed a significant prediction model ($\chi^2 (2) = 12.4$, $p = .002$) which explained 38% of the variability in recurrent pneumonia (Nagelkerke $R^2 = 0.38$) and correctly classified 96% of all cases with AUROC 0.94 (95% CI 0.87–1.0).

Discussion

In this retrospective study comparing protocolized BAL within 48 hours of admission to late symptom-triggered BAL for intubated trauma patients with head or chest trauma, about half of all patients had a pathologic burden of microorganisms in their airways within 48 hours of admission. Previous studies employing early BAL have reported similar microbiologic findings (21, 22). Wahl et al. [32] reviewed 208 trauma, burn, and general surgery patients and found that 58% of patients who had BAL within 48 hours of initiating mechanical ventilation had a positive culture (10^4 CFU/ml). Minshall et al. [33] performed screening-BAL at 36–48 hours following admission for intubated trauma and general surgery patients, and found that 72 out of 150 specimens were positive ($>5 \times 10^4$ CFU/ml).

One important concept in managing critically ill trauma patients is early discontinuation of antibiotics when cultures are negative and suspicion for a false-negative culture is low. Antibiotic stewardship reduces the development of multi-drug resistant organisms [17–19] and reduces healthcare costs [21, 22]. In this study, it is plausible that E-BAL was therapeutic, given that E-BAL patients more frequently had gross blood visible on FOB than L-BAL patients. This allowed for lavage and extrication of the blood, which is a favorable bacterial culture medium. Together, early recognition of patients with a pathologic burden of microorganisms in their airways (likely due to aspiration), early discontinuation of antibiotics for patients with negative cultures, and removal of blood from the airways may have accounted for fewer total days on antibiotics. The plausibility of this hypothesis may be strengthened by the observations that empiric antibiotic administration appeared to be similar between groups. Regardless, early discontinuation of antibiotic therapy should be weighed against the clinical implications of inadequate antibiotic coverage for patients who will go on to have a positive final culture. Although the prevalence of this scenario was not statistically significant between groups in our study, small sample sizes may have rendered

this analysis underpowered to detect a true difference. Notably, E-BAL culture data identified pneumonia as a condition that was present on admission in over half of all patients meeting protocol criteria, which could have a significant impact on Centers for Medicare & Medicaid Services (CMS) penalties given that these patients likely would have been classified as having nosocomial pneumonia on L-BAL.

Previous work has also demonstrated that empiric antibiotic administration based upon clinical criteria tends to over-treat a significant number of patients. In a prospective analysis of antibiotic utilization for critically ill surgical patients at a tertiary care center, Swoboda et al. [34] reported that 50% of all antibiotic days in their ICU were allocated to empirically treat pneumonia in patients who did not actually have pneumonia based on CPIS and Center for Disease Control criteria. Although empiric antibiotic use must be somewhat generous in order to avoid undertreating a true pneumonia, this study and ours indicate that a substantial proportion of empiric antibiotics targeting pneumonia are unwarranted. The lack of correlation between non-specific clinical indicators of pneumonia (temperature, white blood cell count, and the presence of a localized CXR infiltrate) and quantitative BAL culture positivity illustrates the impact of confounding factors on the clinical diagnosis of pneumonia among severely injured trauma patients. However, these two studies also demonstrate the prevalence of unwarranted initiation of antibiotics, a practice which may not be exonerated by the lack of a flawless non-invasive gold standard diagnostic test.

This study was limited by its propensity to generate false positive results by making multiple comparisons and by selection bias, particularly in selecting a historical control L-BAL cohort that remained intubated for an average of 5 days before BAL was performed. Although we attempted to isolate the effects of BAL timing on outcomes, our data also reflect known differences between patients with early vs. late pneumonia. Several strategies may improve our ability to discontinue empiric antibiotics earlier. Previous studies have shown that preliminary BAL cultures at 24–36 hours correlate well with final culture results [35, 36], and may allow for early and safe discontinuation of antibiotics. Also, as technology evolves, quantitative polymerase chain reaction of BAL samples has the potential to provide excellent diagnostic information within hours of sampling [37]. Also, based on work from Wahl et al. [32] and Minshall et al. [33], broader application of E-BAL for trauma and general surgery patients who do not have head or chest trauma deserves further attention.

Conclusions

Over half of all intubated patients with head or chest trauma had evidence of pneumonia on E-BAL performed within 48 hours of admission. E-BAL was associated with early discontinuation of antibiotics, and E-BAL patients had fewer days on mechanical ventilation, fewer tracheostomies, shorter ICU length of stay, and shorter hospital length of stay compared to L-BAL triggered by clinical suspicion for pneumonia, though these differences may be attributable to a longer interval between intubation and BAL. Although E-BAL and L-BAL patients represent two distinct populations, our data indicate that E-BAL is useful for intubated patients with TBI or chest trauma.

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Highlights

- Early BAL (E-BAL) was performed within 48h for high risk intubated trauma patients
- E-BAL was compared to late BAL (L-BAL) triggered by signs of pneumonia
- 52% of E-BAL cultures were positive, identifying pneumonia present on admission
- E-BAL patients had fewer antibiotics days and better outcomes than L-BAL patients

Figure 1.
Trends in antibiotic utilization (E-BAL: early BAL within 48 hours of admission, L-BAL: late BAL more than 48 hours after admission).

Figure 2.
Comparison of outcomes between groups (E-BAL: early BAL within 48 hours of admission, L-BAL: late BAL more than 48 hours after admission).

Table 1

Trauma patient characteristics at presentation (AIS: Abbreviated Injury Scale, CT: computed tomography, PNA: pneumonia, BSI: bloodstream infection, H₂: histamine₂ receptor, PPI: proton pump inhibitor). Data are reported as mean (95% confidence interval) or n (%).

	E-BAL n = 71	L-BAL n = 61	p
Age	47 (44–51)	49 (44–54)	0.656
Male	62 (87%)	46 (75%)	0.077
Injury Severity Score	26 (24–29)	29 (27–32)	0.089
Head AIS	2.7 (2.4–3.1)	3.2 (2.8–3.6)	0.097
Head AIS 2	57 (80%)	54 (89%)	0.255
Glasgow Coma Scale	8 (7–9)	8 (7–9)	0.937
Blunt trauma	67 (97%)	57 (93%)	0.304
Field intubation	36 (51%)	33 (54%)	0.697
Admission CT findings			
Total rib fractures	4.7 (3.4–6.0)	4.0 (2.8–5.1)	0.372
3 rib fractures	37 (58%)	28 (52%)	0.517
Pulmonary contusion	30 (47%)	27 (50%)	0.735
Aspiration	29 (45%)	21 (39%)	0.482
White blood cell count	14.3 (12.6–16.0)	16.3 (14.4–18.2)	0.123
PaO ₂ :FiO ₂ at intubation	266 (241–291)	280 (253–307)	0.467
Body Mass Index	30 (28–32)	29 (27–31)	0.391
Diabetes mellitus	8 (11%)	10 (16%)	0.392
Immunosuppression	3 (4.2%)	1 (1.6%)	0.388
Active smoker	23 (32%)	12 (20%)	0.099
Bloodstream infection	3 (6%)	7 (12%)	0.227
H ₂ blocker use before culture	58 (82%)	51 (84%)	0.772
PPI use before culture	19 (27%)	15 (25%)	0.776
Ulcer prophylaxis before culture	71 (100%)	60 (98%)	0.279
Pre-culture antibiotics	17 (24%)	17 (28%)	0.607

Table 2

Diagnostic findings (CPIS: Clinical Pulmonary Infection Score; BAL: bronchoalveolar lavage; MSSA: methicillin-sensitive *Staphylococcus aureus*; MRSA: methicillin-resistant *Staphylococcus aureus*). Data are reported as mean (95% confidence interval) or n (%).

Clinical diagnostic findings	E-BAL n = 71	L-BAL n = 61	p
Time from admission to intubation (days)	0.2 (0.0–0.3)	0.1 (0.0–0.1)	0.103
Time from intubation to BAL (days)	1.0 (0.8–1.2)	5.5 (4.9–6.1)	*<0.001
CPIS at the time of BAL	5.1 (4.7–5.5)	6.0 (5.6–6.4)	*0.002
CPIS > 6 at the time of BAL	19 (27%)	22 (36%)	0.249
Gross purulence on BAL	22 (31%)	25 (41%)	0.167
Gross bile/aspirated material on BAL	6 (8%)	2 (3%)	0.235
Gross blood on BAL	15 (21%)	1 (2%)	*0.001
Gram stain positive	23 (33%)	21 (34%)	0.805
Culture positive (10 ⁴ CFU/ml)	37 (52%)	37 (61%)	0.324
Pneumonia	43 (61%)	41 (67%)	0.428
Recurrent pneumonia	3 (4%)	1 (2%)	0.388
Gram negative rods in culture	19 (27%)	31 (51%)	*0.007
Discordant Gram stain and culture	20 (28%)	26 (43%)	0.082
Gram stain positive and BAL negative	3 (4%)	5 (8%)	0.340
Gram stain negative and BAL positive	17 (24%)	21 (34%)	0.185
Community-associated organism in culture	21 (30%)	19 (31%)	0.845
MSSA	10 (14%)	11 (18%)	0.536
<i>Streptococcus pneumonia</i>	7 (10%)	1 (2%)	*0.048
β-hemolytic <i>Streptococcus</i>	0 (0%)	4 (7%)	*0.028
<i>Haemophilus influenzae</i>	5 (7%)	8 (13%)	0.243
<i>Moraxella catarrhalis</i>	1 (1%)	1 (2%)	0.914
Healthcare-associated organism in culture	18 (25%)	25 (41%)	0.056
MRSA	4 (6%)	3 (5%)	0.855
<i>Serratia marcescens</i>	1 (1%)	2 (3%)	0.472
<i>Pseudomonas aeruginosa</i>	2 (3%)	5 (8%)	0.169
<i>Acinetobacter baumannii</i>	1 (1%)	1 (2%)	0.914
<i>Enterobacter cloacae</i>	8 (11%)	9 (15%)	0.551
<i>Escherichia coli</i>	0 (0%)	4 (7%)	*0.028
<i>Klebsiella</i> species	2 (3%)	3 (5%)	0.528
<i>Proteus</i> species	1 (1%)	3 (5%)	0.241
<i>Stenotrophomonas maltophilia</i>	0 (0%)	2 (3%)	0.124
<i>Morganella morganii</i>	0 (0%)	1 (2%)	0.279
<i>Candida albicans</i>	1 (1%)	0 (0%)	0.352
Polymicrobial culture	5 (7%)	16 (26%)	*0.003

Table 3

Clinical prediction models (BAL: bronchoalveolar lavage; ICU: Intensive Care Unit).

Outcome Factors	OR	95% CI	<i>p</i>
Positive BAL			
CPIS > 6	3.6	1.5–8.6	*0.005
Purulence on BAL	3.1	1.4–7.0	*0.007
Recurrent pneumonia			
<i>Enterobacter</i> isolate	10.8	1.02–115	*0.048
ICU length of stay	1.2	1.05–1.3	*0.007