RESEARCH

D-PRISM: a global survey-based study to assess diagnostic and treatment approaches in pneumonia managed in intensive care

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Abstract

Background Pneumonia remains a significant global health concern, particularly among those requiring admission to the intensive care unit (ICU). Despite the availability of international guidelines, there remains heterogeneity in clinical management. The D-PRISM study aimed to develop a global overview of how pneumonias (i.e., community-acquired (CAP), hospital-acquired (HAP), and Ventilator-associated pneumonia (VAP)) are diagnosed and treated in the ICU and compare differences in clinical practice worldwide.

Methods The D-PRISM study was a multinational, survey-based investigation to assess the diagnosis and treatment of pneumonia in the ICU. A self-administered online questionnaire was distributed to intensive care clinicians from 72 countries between September to November 2022. The questionnaire included sections on professional profiles, current clinical practice in diagnosing and managing CAP, HAP, and VAP, and the availability of microbiology diagnostic tests. Multivariable analysis using multiple regression analysis was used to assess the relationship between reported antibiotic duration and organisational variables collected in the study.

Results A total of 1296 valid responses were collected from ICU clinicians, spread between low-and-middle income (LMIC) and high-income countries (HIC), with LMIC respondents comprising 51% of respondents. There is heterogeneity across the diagnostic processes, including clinical assessment, where 30% (389) did not consider radiological evidence essential to diagnose pneumonia, variable collection of microbiological samples, and use and practice in bronchoscopy. Microbiological diagnostics were least frequently available in low and lower-middle-income nation settings. Modal intended antibiotic treatment duration was 5–7 days for all types of pneumonia. Shorter durations of antibiotic treatment were associated with antimicrobial stewardship (AMS) programs, high national income status, and formal intensive care training.

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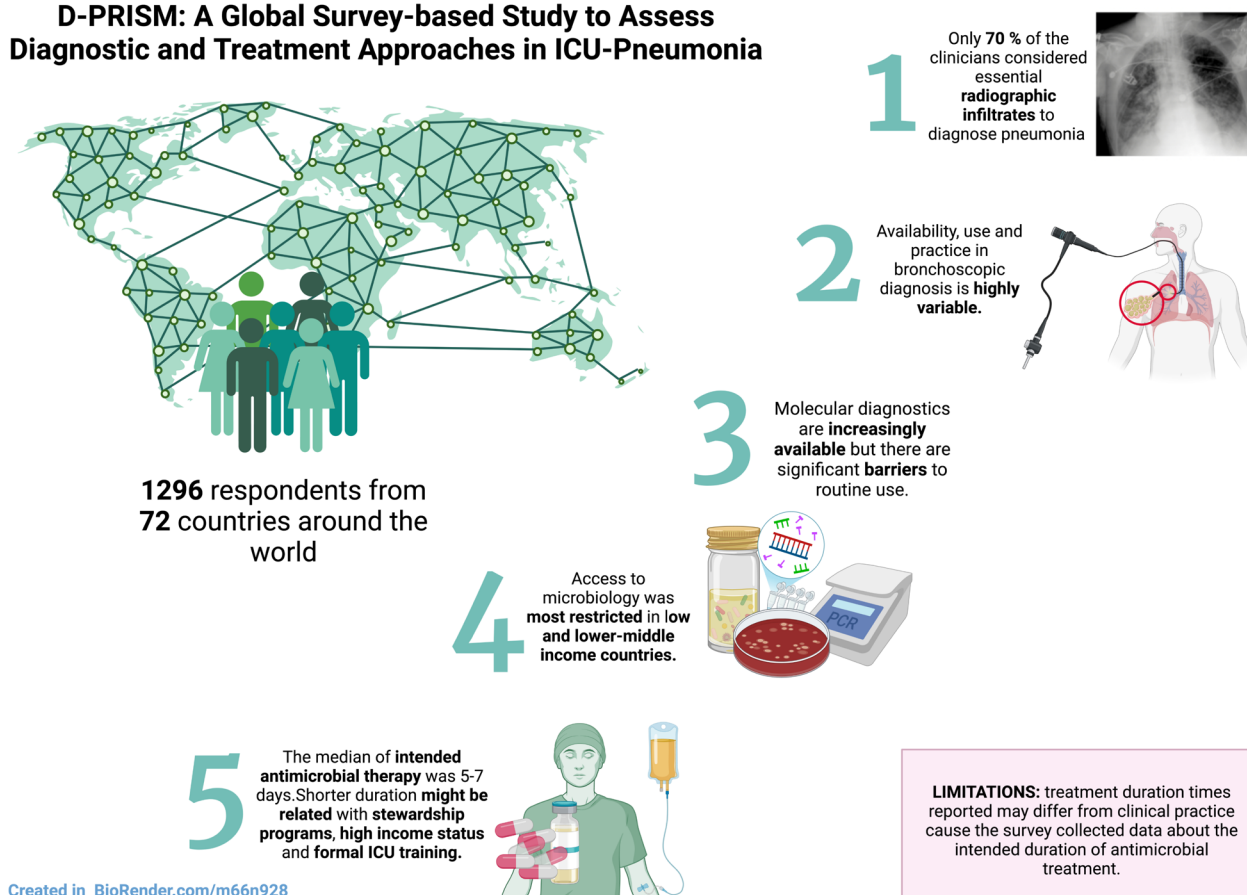Reyes *et al. Critical Care*   (2024) 28:381

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Conclusions This study highlighted variations in clinical practice and diagnostic capabilities for pneumonia, particularly issues with access to diagnostic tools in LMICs were identified. There is a clear need for improved adherence to existing guidelines and standardized approaches to diagnosing and treating pneumonia in the ICU.

Trial registration As a survey of current practice, this study was not registered. It was reviewed and endorsed by the European Society of Intensive Care Medicine.

Keywords Pneumonia, Community-acquired, Hospital-acquired, Ventilator-associated, Intensive care unit (ICU), Antimicrobials, Bronchoscopy, Surveys and questionnaires

Graphical abstract

D-PRISM: A Global Survey-based Study to Assess Diagnostic and Treatment Approaches in ICU-Pneumonia

1296 respondents from **72** countries around the world

1 Only **70 %** of the clinicians considered essential **radiographic infiltrates** to diagnose pneumonia

2 Availability, use and practice in bronchoscopic diagnosis is **highly variable.**

3 Molecular diagnostics are **increasingly available** but there are significant **barriers** to routine use.

4 Access to microbiology was **most restricted in low and lower-middle income countries.**

5 The median of **intended antimicrobial therapy** was 5-7 days. Shorter duration **might be related** with **stewardship programs, high income status** and **formal ICU training.**

LIMITATIONS: treatment duration times reported may differ from clinical practice cause the survey collected data about the intended duration of antimicrobial treatment.

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Background

Pneumonia remains a significant global health concern, particularly among critically ill patients requiring intensive care unit (ICU) admission [1–4]. Patients admitted to the ICU present with broad types of lower respiratory tract infections such as community-acquired pneumonia (CAP), hospital-acquired pneumonia (HAP), ventilator-associated tracheitis (VAT), and ventilator-associated pneumonia (VAP); each presentation has distinct challenges in diagnosis and treatment [5–7]. Pneumonia is responsible for a substantial healthcare burden, with estimated costs reaching 10 billion US dollars annually and accounting for more than 2.5 million deaths a year worldwide [1, 6]. Several international guidelines have been published on diagnosing and managing CAP, HAP, and VAP [6, 8–14]; however, the clinical application of these guidelines remains inconsistent due to various factors, including insufficient education, guideline complexity, and organizational barriers contributing to poor

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adherence among healthcare providers. A lack of training and experience can lead to inconsistent application of guidelines [9, 10, 15, 16].

Although the fundamental definition of pneumonia, namely the presence of alveolar inflammatory infiltration triggered by an infecting organism, has remained constant, the assessment methods have changed over time, and with them, our understanding of clinical disease. The lack of immediate and sensitive pathogen diagnostics leads to broad syndromes that predict likely organisms, with CAP and HAP being the most commonly used clinical diagnoses [11]. Additional classifications have been promulgated, including frailty, healthcare exposure, and immunocompetence [12–14]. The emergence of newer technologies, such as lung ultrasound (LUS), allows sensitive bedside assessment [17–19]. Syndromic molecular tests allow for the rapid evaluation of the presence of pathogens [15, 20–23]. These newer assessment modalities require specific equipment, which comes at the cost of both capital investment and training. Each also brings particular challenges, such as inter-operator variability (for LUS), risk of detection of colonising organisms, and missed detection of off-panel organisms for molecular pathogen detection [24].

Despite the prevalence and clinical significance of pneumonia in the ICU, guidelines on the clinical definition, diagnostic investigation, and management show divergence across the globe [25]. There is also a shortage of evidence regarding comparative clinical practice across the domains of diagnosis and management. Identifying the causative microbes in CAP, HAP, and VAP in the ICU remains challenging, with most cases having no identified pathogen [21, 26–30]. The scarcity of evidence regarding practice is most pronounced in low and middle-income countries where the incidence and mortality of pneumonia is greatest [1] and where the resource limitations may further impact diagnostic accuracy and treatment strategies [31, 32].

The D-PRISM study was conducted as a multinational effort to address these critical gaps in the existing literature. It aimed to provide a comprehensive assessment of the clinical practices employed by critical care clinicians in diagnosing and treating pneumonia admitted to the ICU, with a particular focus on CAP, HAP, and VAP. Due to uncertainties around the definition and diagnosis of VAT, we did not include this in our survey, which was intended to focus specifically on pneumonia [33]. The study sought to evaluate the applicability and adherence to existing clinical guidelines, assess the challenges encountered in clinical and microbiological diagnosis, and explore variations in clinical practices by illuminating these crucial aspects.

Methods

This multinational cross-sectional study conducted an online self-administered questionnaire (SurveyMonkey, Momentive, San Mateo, CA) to intensive care clinicians globally between September and November 2022, with responses from 72 countries. The European Society of Intensive Care Medicine (ESICM) invited all its members to participate in the study, and distribution was further achieved through national coordinators identified by the steering committee. This survey did not collect any data that would allow for the identification of respondents. Participation in the survey was entirely voluntary, and respondents provided consent for using their anonymized answers by choosing to participate. IP address registration was used to prevent multiple participation. The IP addresses were removed prior to analysis and not used for any other purpose, ensuring full compliance with data protection and privacy regulations. As an anonymized survey of clinical practice without individual patient data, the UK Health Research Authority waived the requirement for research ethics approval and formal written consent.

Questionnaire

The D-PRISM questionnaire was created by a steering committee of ESICM members with clinical and research experience in diagnosing and managing severe pneumonia. The survey was translated and available in 10 languages, including Arabic, German, Greek, English, Spanish, French, Portuguese, Russian, Turkish, and Chinese. All the questions were discussed and selected by group consensus and contributed to the current state of practice in severe pneumonia (i.e., pneumonia managed in the ICU), with the final survey being piloted within the steering committee. To ensure accuracy and clarity, national coordinators identified by the steering committee reviewed the translations. The final questionnaire had 40 questions and was divided into five sections that evaluate the professional profile (11 questions), diagnosis and treatment of CAP (5 questions), diagnosis and treatment of HAP (6 questions), diagnosis and treatment of VAP (6 questions), and availability of microbiology diagnostic tests (12 questions). It included open, closed, multiple choice, and Likert scale questions. Where frequency of assessment ('always', 'mostly', 'sometimes', 'never') was examined, 'routine use' was considered to be 'always' or 'mostly'. This questionnaire was not externally validated as its purpose was to address and collect the current state of medical practice in managing severe pneumonia in the ICU. The complete questionnaire is available in the supplementary material.

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Pneumonia definition

All the definitions were provided to the participants before the survey competitions and are based on the current American Thoracic Society—Infectious Diseases Society of America (ATS/IDSA) clinical guidance [5, 6, 15], similar to the definitions used in other national and multinational guidelines.

Community-acquired pneumonia (CAP) was defined as pneumonia or suspected pneumonia present at hospital admission or manifesting within 48 h of hospital admission.

Hospital-acquired pneumonia (HAP) was defined as pneumonia or suspected pneumonia that does not present at hospital admission and develops at least 48 h after hospital admission, and it includes non-ventilated ICU patients.

Ventilator-associated pneumonia (VAP) was defined as pneumonia or suspected pneumonia that does not present at ICU admission and develops at least 48 h after initiation of mechanical ventilation. It included patients who developed symptoms within 48 h of extubation.

Participants

We used a convenience sampling strategy; the participant responders were physicians and physicians in training who work in ICUs and were willing to participate in the study. The study's aim, scope, and confidentiality were explained to them. All the answers were anonymous and collected in an Excel worksheet. No remuneration or incentive was offered to participate. We cannot estimate a denominator as staffing figures do not exist for all nations surveyed.

Statistical analysis

All the categorical variables were presented in relative and absolute frequencies. The continuous variables were presented as medians and interquartile ranges (IQR) or mean and standard deviation (S.D.) based on their normality evaluated with the Kolmogorov–Smirnov test ($p < 0.05$). The results were analyzed and described by the type of pneumonia and the World Bank country classification. The questionnaires with more than 25% unanswered questions were excluded from the analysis. All other data fields were analyzed as recorded; no imputation was undertaken for missing data. We performed a multifaceted approach encompassing both bivariable and multivariable analyses to assess factors associated with the intended duration of antibiotic treatment. Variables identified in the univariable analysis with a *p* value < 0.20 were included in the multivariable model [34]. We carried out multivariable analyses, utilizing multiple regression models to assess the impact of multiple independent variables on a dependent variable. Microsoft Excel and SPSS version 29.0 statistical package performed all the descriptive analyses.

We followed the guidelines outlined in the Consensus-Based Checklist for Reporting of Survey Studies (CROSS) [35], with the CROSS checklist in the supplemental section.

Results

In total, 1322 responses were collected from 72 countries, 26 invalid responses were excluded 25% or greater missing data (Fig. 1). Just under half of the respondents were from high-income countries, 35% were from upper-middle-income countries, and 16% were from low- and lower-middle-income countries (Table 1, Figs. S1, S2). Notable features are the dominance of respondents from teaching or university hospitals (71%) and mixed medical/surgical units (78%), with this dominance noted across all national income levels (Table S1). The criteria discriminated by World Bank income classification are shown in Table S2. Hospitals were generally mid-sized, with a median of 526 beds and 20 ICU beds. Specialization in Intensive Care Medicine was reported by 79%, with just over 1/3rd of these reporting an additional specialization. Respondents were mainly experienced, with 70% having five or more years of post-graduate ICU experience (Table 1). Having an antimicrobial stewardship (AMS) program and/or pneumonia-specific antibiotic protocols and/or local guidelines were widely reported, being present in 80% and 79% of hospitals, respectively (Table 1).

Community-acquired pneumonia

Although respondents almost universally assessed clinical and radiological features in patients with suspected CAP (Table 2), only 65% considered the presence of positive findings in both essential for the diagnosis (individually, 64% reported clinical criteria essential, 71% radiological criteria). The use of lung ultrasound (LUS) was reported by 29%, with a similar proportion reporting a combination of clinical presentation and LUS for CAP diagnosis (Table 2). Regarding the samples taken at diagnosis, sputum or endotracheal aspirate was the most common microbiological sample taken by 83% of respondents. In mechanically ventilated patients, blind mini-bronchoalveolar lavage (mini-BAL) was reportedly used by 33%. Bronchoalveolar lavage (BAL) was routinely used in 29% of mechanically ventilated patients and 11% of non-mechanically ventilated patients (Table 2). Blood culture was very commonly (86%) reported as "always" sampled (Table 2). Regarding antimicrobial treatment, 64% of respondents' initial empiric regimens included dual therapy with a macrolide, 28% used monotherapy, and 8% (105/1296) used dual therapy, including a

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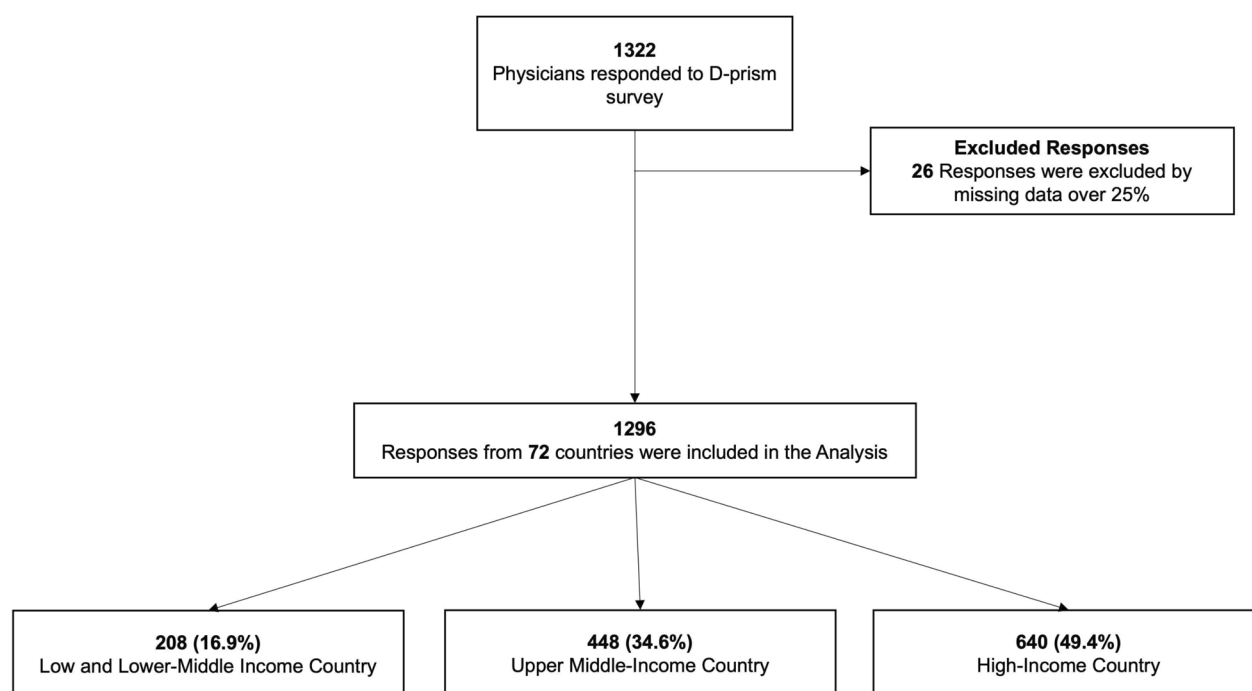
Fig. 1 Study flow chart

non-macrolide (Table 3). If the patient responded to the initial regimen, the reported intended duration of treatment was 5 to 7 days in 82% (Fig. 2, Table 4).

Hospital-acquired and ventilator-associated pneumonia
Regarding HAP and VAP, the frequency of assessments was similar to those reported for CAP. However, the respondents reported a lower frequency of a combination of clinical presentation and radiological signs being used to confirm diagnosis (58% for HAP and 57% for VAP). Usage of clinical presentation and LUS were also lower in these two conditions (9% for HAP and 12% for VAP, respectively) (Table 2). Sputum or endotracheal aspirates were the most requested microbiological sample, reaching 89% for HAP and 91% for VAP. More invasive sampling in the form of blind mini-BAL or formal broncho-alveolar lavage approached 40% for both HAP and VAP. In contrast to CAP, 36% of the respondents considered the usage of blood cultures for HAP and VAP unnecessary (Table 2). Regarding empiric antimicrobial therapy, 39% of respondents preferred dual treatment with coverage for resistant organisms in HAP, whilst for VAP, the rate increased to 48%. The remaining clinicians indicated selective use of dual therapy in patients at higher risk of multi-drug resistant organisms (Table 5). Over half of all respondents reported antibiotic 'timeouts' or mandated reviews at 48–72 h (Table S3). Relative to CAP, where 87% reported the duration of treatment as

5–7 days, the duration of antimicrobial therapy following an initial improvement was longer in HAP and VAP, with 40% and 47%, respectively, reporting a duration of greater than 7 days (Fig. 2, Table S2).

Factors associated with the treatment duration
Univariable analysis was performed to identify factors associated with the intended treatment duration. The multivariable model included variables with a $p < 0.20$ in the initial univariable analysis [34]. Odds ratios (OR) were calculated based on the exponentials of the coefficients obtained by the final model and presented in forest plots (Fig. S3 panels A–C). CAP, HAP, and VAP responses were compared with an intended treatment duration of less than or equal to 7 days. The models demonstrated a good fit as indicated by a Hosmer and Lemeshow test p value of ($p = 0.76$) for CAP, (0.08) for HAP, and ($p = 0.42$) for VAP. Also, an acceptable discriminatory power as indicated by an AUC ROC value of (0.65) for CAP, (0.67) for HAP, and (0.68) for VAP. For CAP, the characteristics associated with treatment ≤ 7 days (Odds Ratio [95% Confidence Interval] p value) were being an intensivist (1.47 [1.00–2.15] $p = 0.04$), having an AMS program (1.93 [1.33–2.78] $p < 0.001$), diagnostic criteria that combined clinical presentation and radiological requirements (1.43 [1.02–2.00] $p = 0.034$) and dual therapy with a macrolide (1.78 [1.28–2.47] $p < 0.001$) (Fig. S3A, Table S4).

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Table 1 Characteristics of the respondents

Characteristics	N = 1296
Region	
Asia	484 (37%)
Europe	406 (31%)
Central and South America	154 (12%)
Sub-Saharan Africa	86 (7%)
Australasia	58 (5%)
North America	66 (5%)
North Africa	42 (3%)
Income level	
High-income	640 (49%)
Upper-middle income	448 (35%)
Lower-middle income	201 (16%)
Low-income	7 (0.5%)
Hospital	
University/teaching hospital	913 (71%)
Community district hospital	338 (26%)
Remote and rural hospital	41 (3%)
ICU-unit	
General ICU (medical and surgical)	1004 (78%)
Medical ICU	161 (12%)
Surgical ICU	73 (6%)
Cardiac ICU	34 (3%)
Neuro ICU	24 (2%)
Hospital size	
Hospital Beds, median (IQR)	526 (264–1000)
ICU beds, median (IQR)	20 (12–31)
Protocol of hospital	
Antimicrobial stewardship program	1023 (79%)
Local Antimicrobial Guidelines	1033 (80%)
Medical specialist	
Intensive care physician	1005 (78%)
Anaesthesiologist	107 (8%)
Respiratory Physician	79 (6%)
Internal medicine physician	34 (3%)
Infections disease physician	25 (2%)
Emergency physician	8 (0.6%)
Others*	3838 (3%)
Postgraduate ICU experience	
> 10 years	610 (47%)
5–10 years	303 (23%)
< 5 years	381 (29%)

*Other medical specialities, including cardiology (3), family physician (4), gastroenterologists (1), geriatricians (1), haematologists (1), nephrologists (3), surgeons (9), Orthopaedics (1), Rehabilitation physician (1), Physician not otherwise specified (10) paediatricians (3), medical student (1)

For HAP, the factors associated with treatment less than 7 days (Odds Ratio [95% Confidence Interval] p value) were being an intensivist (1.46 [1.09–1.96] $p = 0.01$), having an AMS program (1.79 [1.35–2.39] $p = <0.001$), being from a high-income country (1.45 [1.13–1.87] $p = 0.004$), having an antibiotic time out (1.46 [1.15–1.85] $p = 0.002$) and the use of monotherapy (2.55 [1.72–3.77] $p < 0.001$). We also identified that for HAP standard dual-therapy covering methicillin-resistant *Staphylococcus aureus* (MRSA), multi-drug resistant pathogens (MDRP) and *Pseudomonas* spp. (0.68 [0.53–0.87] $p = 0.003$) was a factor related to a treatment duration of more than 7 days (Fig. S3B, Table S5). For VAP the factors associated with treatment less than 7 days were having an AMS program (1.74 [1.30–2.33] $p < 0.001$), being from high-income country (1.62 [1.26–2.07] $p < 0.001$), having an antibiotic time-out (1.46 [1.16–1.85] $p = 0.001$) and the use of monotherapy (3.22 [2.09–4.97] $p < 0.001$) (Fig. S3C, Table S6).

Bronchoscopy

In low and lower-middle-income countries, 61% of respondents reported having bronchoscopy available, but only 29% could perform this exam at any time (24-h availability), with 20% reporting restricted daily availability (Table 6). By contrast, bronchoscopy availability was nearly universal in high-income nations (97%), with 76% having 24-h availability. Upper-middle-income nation respondents indicated similar overall availability of bronchoscopy at 90%, but more restricted hours and days than those from high-income nations (Table 6).

Training in bronchoscopy was variable: among high and upper-middle-income country respondents, 36% and 43% reported formal and informal training, respectively (Table 6), with similar rates between fully qualified specialists and trainees/residents (Table 7). Consistent with trends in the availability of bronchoscopy, those in low/lower-middle-income nations were less likely to report formal or informal training (Table 6).

Where bronchoscopy was available, 58% of respondents reported intensivists as the sole providers, with upper and low/low-middle-income respondents more commonly relying on specialists from outside the ICU for service provision (Table 6). Confidence in bronchoscopy was assessed by a 10-point Likert scale, which demonstrated a relationship with the degree of training, as did specialisation in respiratory medicine (Table 7). The lavage volume also varied with self-reported training status and specialisation in respiratory medicine (Table 7). A weak but significant positive correlation existed between confidence in bronchoalveolar lavage and volume used ($r = 0.25$ $p < 0.001$). Notably, even amongst the most confident and highly trained bronchoscopists, the median lavage volume was 50 ml, well below the 100–200 ml recommended in bronchoscopy guidelines to achieve adequate alveolar lavage [36].

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Table 2 Respondents' assessment rates for diagnostic criteria

| Diagnostic criteria	CAP n = 1296	HAP n = 1296	VAP n = 1296
Clinical presentation**	1235 (95%)	1234 (95%)	1218 (94%)
Radiological criteria			
Chest X-ray or CT scan**	1257 (97%)	1259 (97%)	1244 (96%)
Lung ultrasound**	379 (29%)	405 (31%)	443 (34%)
Clinical and radiological criteria			
Clinical presentation and Chest X-ray or CT scan*	845 (65%)	747 (58%)	742,742 (57%)
Clinical presentation and lung ultrasound*	362 (28%)	115 (9%)	151,151 (12%)
Laboratory tests performed at diagnosis			
Sputum or endotracheal aspirate**	1070 (83%)	1153 (89%)	1174 (91%)
Blind mini-bronchoalveolar lavagelavage**	430 (33%)	507 (39%)	527 (41%)
Bronchoalveolar lavage**	381 (29%)	500,500 (39%)	521,521 (40%)
Blood culture*	803 (62%)	835,835 (64%)	847,847 (65%)

Clinical presentation included the following signs and symptoms: positive findings on auscultation such as bronchi, crepitations, wheeze, breathlessness, purulent sputum, impaired oxygenation or ventilation; Radiological findings included: CXR or C.T. showing lobar infiltration or bronchogram or diffuse or patchy shadowing; Sonological findings include USS showing consolidation or bronchogram

*Frequencies reported only include the "always" response

**Frequencies reported the combination of "always" and "mostly" responses

Table 3 Antimicrobial regimen used in CAP patients

Empirical treatment CAP n = 1296	
Antibiotic regimen	
Monotherapy	357 (27.5%)
Dual therapy with macrolide	827 (63.8%)
Dual therapy with non-macrolide	105 (8.1%)
Not answered	7 (0.5%)
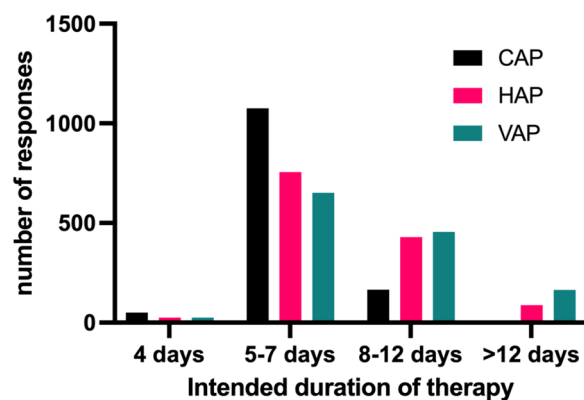
Fig. 2 Duration of antibiotic regimen by disease. *CAP* Community-acquired pneumonia, *HAP* Hospital-acquired pneumonia, *VAP* Ventilator-associated pneumonia

Microbiological tests

Conventional microbiological cultures are reported quantitively for sputum by 54% of responding institutions, for blind mini-BAL by 43%, for BAL by 57%, and for blood by 48%. While sputum and blood cultures were almost universally available (98% and 99% overall), there was a noticeable income-related disparity, with these tests being less accessible in low and lower-middle-income ICUs (Tables 6 and S7). This gap was even more pronounced for deep lung sampling techniques, where 13% of respondents reported mini-BAL being unavailable, and 3% indicated BAL was unavailable (Tables 6 and S7).

The use of molecular microbiological tests varied between countries. In low-middle-income and upper-middle-income countries, the availability of multiplex molecular tests was relatively frequently reported at 44% and 64%, respectively. The Legionella urinary test was the most reported in high-income countries at 92% (Table 6). The pneumococcal urinary antigen test was available by 75%; however, low/lower-middle-income countries reported low availability of these assays—only 22% had access to the Legionella antigen test and 13% to the Pneumococcal antigen test. Regarding barriers to using multiplex testing, 44% of respondents reported a barrier to access of some type, of which the most common was the cost of the test, reported by 69%. The named multiplex

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Table 4 Intended treatment duration

Intended antimicrobial duration	All cohort	High income countries	Upper-middle-income countries	Low and low-middle income countries
CAP				
< 5 days	51 (3.9%)	16 (2.5%)	20 (4.5%)	15 (7.2%)
5–7 days	1059 (81.7%)	546 (85.3%)	355 (79.2%)	158 (75.9%)
> 7 days	174 (11.1%)	71 (11.0%)	71 (15.8%)	32 (15.4%)
Not answer	12 (0.9%)	7 (1%)	2 (0.5%)	3 (1.5%)
HAP				
< 5 days	25 (1.9%)	6 (0.9%)	8 (1.8%)	11 (5.2%)
5–7 days	743 (57.3%)	421 (65.8%)	226 (50.4%)	96 (46.1%)
> 7 days	515 (39.7%)	207 (32.3%)	211 (47.1%)	97 (46.6%)
Not answer	13 (1.0%)	6 (1%)	3 (0.6%)	4 (2%)
VAP				
< 5 days	24 (1.8%)	5 (1%)	10 (2.2%)	9 (4.3%)
5–7 days	643 (49.6%)	380 (59.3%)	186 (41.5%)	77 (37.1%)
> 7 days	615 (47.4%)	250 (39.1%)	246 (54.9%)	119 (57.2%)
Not answer	14 (1.0%)	5 (1%)	6 (1.2%)	3 (1.5%)

CAP Community-acquired pneumonia, *HAP* Hospital-acquired pneumonia, *VAP* Ventilator-associated pneumonia

Table 5 The antimicrobial regimen used in HAP and VAP patients

Antibiotic regimen	HAP n = 1296	VAP = 1296
Monotherapy for all patients	209 (16.1%)	163 (12.5%)
Monotherapy for low risk of resistant organisms	572 (44.1%)	511 (39.4%)
Dual therapy, including coverage for resistant organisms (e.g. MRSA/MDR pseudomonas) for all patients	510 (39.3%)	616 (47.5%)
N/A	5 (0.3%)	6 (0.4%)

test most frequently reported was the BioFire film array (reported by 23%), although 31% did not know which specific test was used at their institution (Fig. S4).

Discussion

The D-PRISM study provides insights into the current clinical diagnosis and management of pneumonia in the ICU. To the best of our knowledge, it is the largest and most geographically widespread study of clinical approaches to severe pneumonia yet reported. We found similar approaches to clinical and radiological diagnosis by national income level but with more divergence regarding bronchoscopic sampling and microbiological testing. Antimicrobial duration was associated with several unit-based factors.

There are significant variations in clinical practices among critical care clinicians. While assessing clinical and radiological features was nearly universal, 1/3rd of clinicians did not feel that the radiographic feature of pulmonary infiltrates was essential for diagnosis, whether for HAP, VAP, or CAP. This reflects results from

a single-nation VAP-only study where 33% of respondents did not require radiographic findings to diagnose pneumonia [37]. It should be noted that while most guidelines advocate radiographic evidence of infiltration for diagnosing CAP [38, 39], HAP, and VAP [5, 6, 40, 41], several HAP and VAP guidelines identify issues with the sensitivity and specificity of radiographic evaluation [5, 6, 41] and advise starting antibiotics based on clinical suspicion alone. This may reflect clinicians' lack of certainty in using imaging as a confirmatory tool. Notably, however, most of the randomized clinical studies carried out to treat VAP and CAP include the radiological criteria for diagnosis as essential and do not encourage the start of empirical treatment without confirming radiographic infiltrates [42, 43]. Of note, in our study, only 60% of respondents reported adhering to the recommended diagnostic criteria, highlighting a potential gap between guideline recommendations and clinical practice, which could drive increased use of antibiotics. The absence of radiographic assessment will also make the differentiation of VAT from pneumonia more challenging. The role

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Table 6 Availability of diagnostic tests in countries classified by The World Bank income classification

Diagnostic test	World Bank classification		
	High-income n = 640 (%)	Upper-middle income n = 448 (%)	Low and lower-middle income n = 208 (%)
Bronchoscopy	621 (97%)	406 (91%)	126 (61%)
Availability of bronchoscopy			
Always	488 (76%)	230 (51%)	56 (26%)
Specific hours every day	86 (13%)	84 (19%)	36 (17%)
Specific weekdays	47 (7%)	92 (20%)	33 (16%)
Who performs the bronchoscopy			
Intensive care specialist	547 (86%)	190 (42%)	66 (31%)
Respiratory Physician from outside of the ICU unit	66 (10%)	136 (30%)	54 (25%)
Not answered	8 (1%)	80 (18%)	6 (3%)
BAL			
Level of training performing			
Formal training	233 (36%)	188 (42%)	54 (26%)
Informal training	318 (50%)	125 (28%)	69 (33%)
No training	67 (11%)	108 (24%)	53 (26%)
Microbiological test			
Not available			
Pneumococcal urinary test	135 (21%)	293 (65%)	150 (72%)
Legionella urinary test	40 (6%)	224 (50%)	127 (61%)
Single organism PCR	231 (36%)	173 (39%)	94 (45%)
Multiplex PCR test	95 (15%)	100 (22%)	79 (38%)
Available			
Pneumococcal urinary test	480 (75%)	83 (19%)	27 (13%)
Legionella urinary test	586 (92%)	162 (36%)	47 (23%)
Single organism PCR	318 (50%)	187 (42%)	74 (36%)
Multiplex PCR test	501 (78%)	285 (64%)	91 (44%)
Conventional cultures			
Not available			
Sputum	3 (0.4%)	7 (2%)	9 (4%)
Blind mini BAL	88 (14%)	60 (13%)	25 (12%)
BAL	1 (0.1%)	13 (3%)	24 (12%)
Blood	0 (0%)	0 (0%)	9 (4%)

of antibiotic prescribing in VAT remains uncertain and controversial [33].

The frequency of microbiological sampling differed between the sub-types of pneumonia, with 52% of respondents always taking samples in CAP but rising to 62% and 74% in HAP and VAP, respectively. However, this was well short of the 100% microbiological sampling in the guidelines for severe CAP [8, 38, 39] and HAP/VAP [5, 6, 40, 41]. Microbiological testing is recommended to guide antimicrobial therapy for severe CAP and nosocomial lower respiratory infections, such as HAP and VAP. However, the strength of these recommendations is generally conditional with low quality of evidence, reflecting the balance between potential benefits and the limitations of current diagnostic methods [15, 44]. It should also be noted that only in 38% of cases of pneumonia is it possible to identify the microorganism causing pneumonia [26] and that truly unbiased molecular detection remains a research tool [45]. The higher sampling rates in HAP and VAP cases may reflect increasing diagnostic uncertainty where non-infectious mimics are more common [46]. The use of deeper lung samples, including mini-BAL and bronchoscopic BAL, was also more common in ventilated HAP and VAP than ventilated CAP, perhaps reflecting greater concern regarding contamination of the proximal respiratory tract in those who have been hospitalized or ventilated for longer [47, 48]. Notably, however, guideline advocacy for invasive diagnostic techniques in this area is caveated by uncertainty as to the balance of risks of bronchoscopy against the benefits of improved antimicrobial stewardship [5, 41]; indeed, the U.S. guidelines weakly advise against invasive sampling [6].

Conventional microbiology was widely used, although it is notable that a significant proportion of low-and-middle-income respondents did not have this diagnostic modality available. The influence of the recent COVID-19 pandemic could be detected through the widespread availability of single-plex polymerase chain reaction testing. Although multiplex testing was also more widely available than anticipated, this may reflect the respondents' teaching/university hospital bias. While multiplex PCR offers better pathogen detection and more precise treatment options, its impact on patient outcomes remains underexplored. Research suggests that multiplex PCR testing can help start the correct antibiotics earlier and reduce the need for broad-spectrum treatments. However, the strength of this evidence varies; not all studies show the same level of benefit, and it is not yet clear whether this translates into better clinical or microbiological outcomes [23, 49, 50]. Furthermore, although we did not ascertain how frequently these tests were used, many respondents reported barriers to use, especially in lower-income settings where most respondents reported cost and reagent availability as barriers.

Although bronchoscopic lavage was reported as a routine ('always or mostly') diagnostic test in 40% of HAPs and VAPs, training in this technique is highly variable, and a lack of formal training was associated with lower

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Table 7 Training in bronchoscopy description

Type of training	Degree seniority			BAL characteristics	
	Consultant/specialist in intensive care n = 1048	Trainee/resident in intensive care n = 202	Other n = 46	Confidence in performing BAL, median (IQR)*	Instilled volume (mL) used for BAL, median (IQR)**
Formal training in BAL	392 (37%)	68 (34%)	15 (33%)	8 (7–10)	50 (20–100)
Informal training in BAL	433 (41%)	65 (32%)	14 (30%)	7 (5–8)	30 (15–60)
No training in BAL	154 (15%)	60 (30%)	14 (30%)	2 (0–5)	20 (10–50)
Training in BAL not reported	69 (7%)	9 (4%)	3 (7%)	4 (0–8)	20 (10–100)

BAL Bronchoalveolar lavage

*Confidence in performing BAL was measured on a self-perception scale from (0 to 10), with 0 being no confidence at all and 10 being the highest confidence value

**The standard BAL approach involves instilling the sterile saline in increments of 20–50 mL per aliquot, usually in three to five separate aliquots, to achieve adequate lavage and sampling

operator confidence and the use of smaller lavage volumes. For lavage to sample the alveolar space (primary site of pneumonia), a sufficient volume is required to form a continuous column from the scope to the alveoli, typically estimated to be at least 100 ml in an adult [36]. The median volume used was 30 ml, and 77% of respondents used < 100 ml, which suggests that in most patients, the alveolar space is not being adequately sampled, and as such, results may not be comparable to clinical studies where high-volume lavage is used [47, 51].

The duration of intended antimicrobial therapy was reported to be 5–7 days for CAP, in line with recommendations from the ATS/IDSA guidelines [15], with longer durations reported for the treatment of HAP and VAP, likely reflecting concerns regarding resistant organisms, especially non-fermenting Gram-negatives such as Pseudomonas aeruginosa [52]. However, it is possible that real-world practice differs from intended antimicrobial duration. A recent study by Yi et al. found that the median duration of antimicrobial therapy was 9.5 days, with 70% of cases being assessed as excessive duration [53]. Antimicrobial stewardship interventions have previously demonstrated a reduction in the duration of therapy and hospital length of stay, improving antimicrobial-guided treatment and adherence to local and international guidelines [54–58]. Respondents from centres that reported the presence of an AMS program, which is a structured programme of collection, analysis, and feedback of data around antimicrobial prescribing and antibiotic stewardship interventions, tended to have shorter intended durations of antimicrobial courses. This effect was also seen with antibiotic time-out at 48–72 h, a structured intervention to formally review the requirement for ongoing antibiotic therapy after the time-period indicated. However, the relationships identified by regression analysis need to be considered exploratory given the convenience sample nature of this study.

Although the higher rates of bacterial resistance in lower-middle and low-income countries might be expected to impact antimicrobial therapy duration, in our study, the length of intended therapy for CAP did not differ by national income status. However, higher national income status was associated with shorter durations for HAP and VAP. This data cannot determine whether this apparently increased duration was driven by perceived or actual rates of antimicrobial resistance. In line with recommendations from ATS/IDSA [38] and the British Thoracic Society guidelines [59], most respondents reported using dual therapy with a macrolide as the first line for CAP. Perhaps reflecting the uncertainty and reported risk of harm from routine use of dual therapy in HAP and VAP [60], treatment here was more cautious, with 40% reporting dual therapy for all patients and 44% reporting selective use when patients were deemed at high risk of multi-drug resistant organisms.

This study has several advantages over previous studies in this area, as the number of respondents and coverage from 72 countries increased the representativeness of the findings. However, it has some limitations, notably that the response rate cannot be calculated as it was distributed beyond members of the ESICM. Furthermore, the responses are skewed towards academic centres and may not reflect practice in other settings. Although we took measures to ensure linguistic accuracy and cultural relevance, the absence of a formal validation process for the survey may introduce variability in the interpretation of questions across different languages. Additionally, only 16% of the respondents were from low and lower-middle-income countries. This disparity might reflect unequal access to internet-based resources and lower participation in international societies. The study did not collect data about steroid use or specific local antimicrobial regimens. Furthermore, we restricted our analysis to the 'conventional pharmacopoeia' and did not explore the use

of herbal or other traditional remedies. Likewise, the role of other specialists as consultants from outside the ICU was not evaluated. We did not break pneumonia down into illnesses arising from different classes of organisms, e.g., viral, atypical, and extracellular bacteria, as this data is frequently unavailable at the time of initial diagnosis. However, it is possible that initial diagnostic and clinical management may differ depending on the suspected or confirmed aetiological agent. The study was based on clinicians' self-assessment of practice and, therefore, cannot be certain of the reports' reliability. Treatment duration times reported may differ from clinical practice as the survey only collected data regarding the intended duration of antimicrobial treatment. Despite these limitations, this study addresses various issues that provide valuable insights into clinicians' behaviour and decision-making processes. These findings invite further exploration of adherence to, and the applicability of, international guidelines through studies involving patient-level data.

Conclusions

In conclusion, we found widespread variations in practice regarding diagnosing severe pneumonia in critical care. While clinicians tend to use similar clinical and radiological criteria for both CAP and HAP/VAP, they show more variability in microbiological sampling methods, and many clinicians deviate from the international guidance on diagnostic approaches. There is increasing availability of techniques such as ultrasound and multiplex molecular testing, but their use is far from universal, and considerable barriers remain to routine implementation. There are significant issues with the availability of bronchoscopy in the ICU, with gaps in the training and experience in its use and evidence of suboptimal sampling techniques. The potential to improve standardisation in the diagnosis and management of pneumonia is considerable and presents opportunities in the future to examine the effects of such a standardisation on patient outcomes. This underscores the need for further observational or audit-based research to assess how closely clinical practice aligns with established guidelines more accurately. This could provide a more robust understanding of the reasons behind these variations and help identify potential barriers to guideline implementation.

Abbreviations

ICU	Intensive care unit
CAP	Community-acquired pneumonia
HAP	Hospital-acquired pneumonia
VAP	Ventilator-associated pneumonia
LMIC	Low middle-income countries
HIC	High-income countries
LUS	Lung ultrasound
ESICM	The European Society of Intensive Care Medicine
IQR	Interquartile ranges
BAL	Bronchoalveolar lavage
mini-BAL	Mini-bronchoalveolar lavage
AMS	Antimicrobial stewardship
MRSA	Methicillin-resistant Staphylococcus aureus
MDRP	Multi-drug resistant pathogens

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13054-024-05180-y.

Additional file 1.

Additional file 2.

Additional file 3.

Additional file 4.

Availability of data and materials

The dataset supporting the conclusions of this article is included within the article (and its additional files).

Declarations

Ethics approval and consent to participate

This multinational cross-sectional study conducted an online self-administered questionnaire to intensive care clinicians. As an anonymized survey of clinical practice without individual patient data, the requirement for research ethics approval and formal written consent was waived by the UK Health Research Authority.

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Consent for publication
Not applicable.

Competing interests
Nathan D. Nielsen sits on the scientific advisory boards of Adrenomed AG and Inotrem. Jordi Rello received honoraria from the Speakers' Bureau and consultancies from ROCHE, Pfizer & MSD. Andrew Conway Morris reports speaking fees from Biomerieux, Thermo-Fisher, Fischer and Paykel and Boston Scientific, he sits on the scientific advisory board of Cambridge Infection Diagnostics. Pedro Póvoa reports honoraria for lectures and advisory boards from Merck Sharp & Dohme, Gilead, Mundipharma and Pfizer, and advisory boards from Merck Sharp & Dohme, Sanofi, Gilead and Biocodex. All other authors report no competing interests.

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