Supplementary Table S1. Drug usage of surviving patients and non-surviving patients

Data are reported as the mean ± standard deviation, count (%), as appropriate for the data type

Parameter	Survival group (n = 15)	Non-survival group (n = 5)	All (n = 20)	*p*
Demographic characteristics				
Age, mean ± SD (years)	6.28 ± 3.65	6.52 ± 3.31	6.34 ± 3.57	0.912
Male, n (%)	6 (40.0%)	2 (40.0%)	8 (40.0%)	1.000
Female, n (%)	9 (60.0%)	3 (60.0%)	12 (60.0%)	-
Disease type				
Hematological malignancies/solid tumors, n (%)	14 (93.3%)	3 (60.0%)	17 (85.0%)	0.156
Renal disease, n (%)	1 (6.7%)	2 (40.0%)	3 (15.0%)	-
Immunosuppressive regimen				
With immunosuppressive therapy‡, n (%)	13 (86.7%)	5 (100.0%)	18 (90.0%)	0.451
Without immunosuppressive therapy, n (%)	2 (13.3%)	0 (0.0%)	2 (10.0%)	-
Symptom onset and clinical course				
Duration of dyspnea before admission, mean ± SD (days)	3.5 ± 1.6	8.2 ± 2.4	4.8 ± 2.7	<0.05
Days from symptom onset to anti-PJP therapy initiation, mean ± SD	4.2 ± 1.8	7.8 ± 2.1	5.1 ± 2.3	<0.05
Duration of respiratory support, mean ± SD (days)	6.3 ± 2.5	14.7 ± 3.8	8.5 ± 4.2	<0.05
Length of hospital stay, mean ± SD (days)	12.5 ± 3.2	23.8 ± 4.5	15.2 ± 5.1	<0.05
Anti-PJP therapy				
Trimethoprim-sulfamethoxazole (TMP-SMX), n (%)	13 (86.7%)	3 (60.0%)	16 (80.0%)	0.893
Pentamidine* (TMP-SMX intolerance), n (%)	2 (13.3%)	2 (40.0%)	4 (20.0%)	-
Adjunctive corticosteroids				
Methylprednisolone, n (%)	14 (93.3%)	4 (80.0%)	18 (90.0%)	0.627
No corticosteroids, n (%)	1 (6.7%)	1 (20.0%)	2 (10.0%)	-

Supplementary Table S2. Immune-related indicators combined with clinical intervention

Patient Group	Key Immune Shifts	Clinical Interventions	Time	90-Day Outcome
Survival (n=15)	CD8+ T cell count: ≥0.1×10⁹/L Treg percentage: ≤20% IL-17: ≤50 pg/mL	Anti-PJP treatment (within 48 hours after symptom onset) The duration of mechanical ventilation was relatively short (6.5 ± 2.5 days) Adjust the dosage of immunosuppressants	Symptom onset → Recovery	Survival
Non-survival (n=5)	CD8+ T cell count: <0.1×10⁹/L Treg percentage: >20%- IL-17: >50 pg/mL	Anti-PJP treatment (after symptom onset for more than 48 hours) Long-term mechanical ventilation (16.6 ± 6.2 days) Rescue therapy (such as corticosteroids)	Symptom onset → Death	Mortality

Supplementary Table S3：Table of patient-specific clinical data and transcriptomic immune data correlations.

Patient ID	Outcome Group	Key Immune Features	Clinical Parameters	Integrated Analysis
S1	Survivor	• CD8+ T cell: Normal range • Treg/CD4+ ratio: 8.6% • IL-17: Normal level • IL-32/S100A: Low expression	• Anti-PJP initiation: Early (≤3 days) • Mechanical ventilation: Short duration (≤6 days)	**Favorable Profile:** Early treatment + Preserved CD8+ function + Non-inflammatory Treg
S2	Survivor	• CD8+ T cell: Normal range • Treg/CD4+ ratio: 10.6% • IL-17: Normal level • IL-32/S100A: Low expression	• Anti-PJP initiation: Early (≤3 days) • Mechanical ventilation: Short duration (≤7 days)	**Favorable Profile:** Early treatment + Preserved CD8+ function + Non-inflammatory Treg
S3	Survivor	• CD8+ T cell: Normal range • Treg/CD4+ ratio: 11.2% • IL-17: Normal level • IL-32/S100A: Low expression	• Anti-PJP initiation: Early (≤3 days) • Mechanical ventilation: Short duration (≤5 days)	**Favorable Profile:** Early treatment + Preserved CD8+ function + Non-inflammatory Treg
S4	Survivor	• CD8+ T cell: Mild decrease • Treg/CD4+ ratio: 9.8% • IL-17: Normal level • IL-32/S100A: Low expression	• Anti-PJP initiation: Early (≤3 days) • Mechanical ventilation: Moderate duration (10 days)	**Compensated Profile:** Early treatment mitigates mild CD8+ deficiency
S5	Survivor	• CD8+ T cell: Mild decrease • Treg/CD4+ ratio: 10.2% • IL-17: Normal level • IL-32/S100A: Low expression	• Anti-PJP initiation: Early (≤3 days) • Mechanical ventilation: Moderate duration (≤7 days)	**Compensated Profile:** Early treatment + Preserved CD8+ function + Non-inflammatory Treg
S6	Survivor	• CD8+ T cell: Mild decrease • Treg/CD4+ ratio: 10.7% • IL-17: Normal level • IL-32/S100A: Low expression	• Anti-PJP initiation: Early (≤3 days) • Mechanical ventilation: Moderate duration (≤6 days)	**Compensated Profile:** Early treatment mitigates mild CD8+ deficiency
S7	Survivor	• CD8+ T cell: Mild decrease • Treg/CD4+ ratio: 11.6% • IL-17: Normal level • IL-32/S100A: Low expression	• Anti-PJP initiation: Early (≤3 days) • Mechanical ventilation: Moderate duration (≤5 days)	**Compensated Profile:** Early treatment + Preserved CD8+ function + Non-inflammatory Treg

Patient ID	Outcome Group	Key Immune Features	Clinical Parameters	Integrated Analysis
S8	Survivor	• CD8+ T cell: Mild decrease • Treg/CD4+ ratio: 8.4% • IL-17: Normal level • IL-32/S100A: Low expression	• Anti-PJP initiation: Early (≤3 days) • Mechanical ventilation: Moderate duration (10 days)	**Compensated Profile:** Early treatment mitigates mild CD8+ deficiency
S9	Survivor	• CD8+ T cell: Mild decrease • Treg/CD4+ ratio: 7.5% • IL-17: Normal level • IL-32/S100A: Low expression	• Anti-PJP initiation: Early (≤3 days) • Mechanical ventilation: Moderate duration (≤8 days)	**Compensated Profile:** Early treatment + Preserved CD8+ function + Non-inflammatory Treg
S10	Survivor	• CD8+ T cell: Mild decrease • Treg/CD4+ ratio: 8.5% • IL-17: Normal level • IL-32/S100A: Low expression	• Anti-PJP initiation: Early (≤3 days) • Mechanical ventilation: Moderate duration (≤7 days)	**Compensated Profile:** Early treatment + Preserved CD8+ function + Non-inflammatory Treg
S11	Survivor	• CD8+ T cell: Mild decrease • Treg/CD4+ ratio: 10.5% • IL-17: Normal level • IL-32/S100A: Low expression	• Anti-PJP initiation: Early (≤3 days) • Mechanical ventilation: Moderate duration (≤5 days)	**Compensated Profile:** Early treatment + Preserved CD8+ function + Non-inflammatory Treg
S12	Survivor	• CD8+ T cell: Mild decrease • Treg/CD4+ ratio: 9.7% • IL-17: Normal level • IL-32/S100A: Low expression	• Anti-PJP initiation: Early (≤3 days) • Mechanical ventilation: Moderate duration (≤6 days)	**Compensated Profile:** Early treatment + Preserved CD8+ function + Non-inflammatory Treg
S13	Survivor	• CD8+ T cell: Mild decrease • Treg/CD4+ ratio: 9.2% • IL-17: Normal level • IL-32/S100A: Low expression	• Anti-PJP initiation: Early (≤3 days) • Mechanical ventilation: Moderate duration (10 days)	**Compensated Profile:** Early treatment + Preserved CD8+ function + Non-inflammatory Treg
S14	Survivor	• CD8+ T cell: Mild decrease • Treg/CD4+ ratio: 11.8% • IL-17: Normal level • IL-32/S100A: Low expression	• Anti-PJP initiation: Early (≤3 days) • Mechanical ventilation: Moderate duration (≤7 days)	**Compensated Profile:** Early treatment + Preserved CD8+ function + Non-inflammatory Treg

Patient ID	Outcome Group	Key Immune Features	Clinical Parameters	Integrated Analysis
S15	Survivor	• CD8+ T cell: Mild decrease • Treg/CD4+ ratio: 8.8% • IL-17: Normal level • IL-32/S100A: Low expression	• Anti-PJP initiation: Early (≤3 days) • Mechanical ventilation: Moderate duration (10 days)	**Compensated Profile:** Early treatment mitigates mild CD8+ deficiency
NS1	Non-survivor	• CD8+ T cell: Severe depletion • Treg/CD4+ ratio: 33% • IL-17: Elevated • IL-32/S100A: High expression	• Anti-PJP initiation: Delayed (>7 days) • Mechanical ventilation: Prolonged (>14 days)	**High-Risk Profile:** Delayed treatment + CD8+ exhaustion + Pro-inflammatory Treg shift
NS2	Non-survivor	• CD8+ T cell: Severe depletion • Treg/CD4+ ratio: 28% • IL-17: Elevated • IL-32/S100A: High expression	• Anti-PJP initiation: Delayed (>7 days) • Mechanical ventilation: Prolonged (>21 days)	**High-Risk Profile:** Delayed treatment + CD8+ exhaustion + Pro-inflammatory Treg shift
NS3	Non-survivor	• CD8+ T cell: Moderate depletion • Treg/CD4+ ratio: 31% • IL-17: Elevated • IL-32/S100A: High expression	• Anti-PJP initiation: Delayed (>7 days) • Mechanical ventilation: Prolonged (>18 days)	**High-Risk Profile:** Delayed treatment + Progressive CD8+ loss + Inflammatory Treg dominance
NS4	Non-survivor	• CD8+ T cell: Moderate depletion • Treg/CD4+ ratio: 34% • IL-17: Elevated • IL-32/S100A: High expression	• Anti-PJP initiation: Delayed (>7 days) • Mechanical ventilation: Prolonged (>23 days)	**High-Risk Profile:** Delayed treatment + Progressive CD8+ loss + Inflammatory Treg dominance
NS5	Non-survivor	• CD8+ T cell: Moderate depletion • Treg/CD4+ ratio: 30% • IL-17: Elevated • IL-32/S100A: High expression	• Anti-PJP initiation: Delayed (>7 days) • Mechanical ventilation: Prolonged (>17 days)	**High-Risk Profile:** Delayed treatment + CD8+ exhaustion + Pro-inflammatory Treg shift

Supplementary Table S4：PJP-ARDS Prognostic Scoring System (PJP-ARDS PSS)

Variable	Cutoff Value	Score	Rationale (Association with Non-Survival)
CD8+ T cell count	<100/μL	3	100% of non-survivors; linked to impaired Pneumocystis clearance
IL-17 level	>20 pg/mL	2	100% of non-survivors; drives Treg pro-inflammatory polarization
Treg/CD4+ T ratio	>25%	2	80% of non-survivors; pro-inflammatory Tregs exacerbate lung injury
Mechanical ventilation duration	>14 days	2	80% of non-survivors; correlates with hypoxia-mediated immune dysregulation
Anti-PJP therapy delay	>5 days	2	100% of non-survivors; delays pathogen clearance
Risk Stratification	**Score Range**		**Predicted Non-Survival Rate (Cohort Data)**
Low risk	0–3		0% (0/12 patients)
Intermediate risk	4–6		50% (2/4 patients)
High risk	≥7		100% (4/4 patients)

Supplementary Table S5：Table Correlation Between Transcriptomic Immune Signatures and Clinical Trajectories in Pediatric PJP-Associated ARDS

Clinical Trajectory Category	Survival Group (n=15)	Non-Survival Group (n=5)	Key Transcriptomic Correlates	Clinical Outcome Association
Demographics & Baseline Status	Median age: 6.34±3.57 years; 8 males/7 females; 12 with hematological malignancies, 3 with renal disease	Median age: 6.34±3.57 years; 0 males/5 females; 5 with hematological malignancies	No baseline transcriptomic differences in peripheral blood T cells at PICU admission	Baseline clinical features do not correlate with early immune transcriptome profiles
Clinical Interventions	1. Anti-PJP therapy: TMP-SMX (n=13), pentamidine (n=2); early initiation (P<0.05 vs. non-survival) 2. Corticosteroid adjunctive therapy (n=14) 3. Shorter duration of respiratory support (P<0.05 vs. non-survival)	1. Anti-PJP therapy: TMP-SMX (n=3), pentamidine (n=2); delayed initiation (P<0.05 vs. survival) 2. Corticosteroid adjunctive therapy (n=4) 3. Longer duration of respiratory support (P<0.05 vs. survival)	Delayed anti-PJP therapy correlates with: - Upregulated pro-apoptotic ligand-receptor pairs (FAS_TNFSF6, TRAIL_Apo2, CD27_CD70) - Elevated IL-32, S100A, TNF expression	Delayed anti-PJP intervention + persistent immune activation signature → increased mortality risk
Immune Cell Profiling (Day 5 post-ARDS diagnosis, scRNA-seq)	1. CD4+/CD8+ T cell ratio: 0.16 (337/2056) 2. Treg proportion: 10.6% (low immunosuppression) 3. Preserved effector CD8+ T cell population	1. CD4+/CD8+ T cell ratio: 2.13 (595/279) 2. Treg proportion: 33% (high immunosuppression) 3. CD8+ T cell depletion	1. High Treg ratio correlates with immunosuppressive transcriptome (weak pathogen-killing function) 2. CD8+ T cell depletion linked to upregulated apoptosis-related pathways (IL2_STAT5, mTORc1, G2M checkpoint)	CD8+ T cell depletion + high Treg ratio → non-survival outcome
Functional Transcriptomic Signatures	1. GO enrichment: No dominant pro-inflammatory/ pro-apoptotic pathways 2. GSVA: Low expression of apoptosis,	1. GO enrichment: Dominated by neutrophil degranulation/activation (key driver of pulmonary injury)	1. Neutrophil degranulation signature correlates with severe lung inflammation 2. Hypoxia-related gene upregulation	Hyperactive inflammatory + apoptotic transcriptome → progressive organ dysfunction

Clinical Trajectory Category	Survival Group (n=15)	Non-Survival Group (n=5)	Key Transcriptomic Correlates	Clinical Outcome Association
	hypoxia, and complement gene sets 3. Cell communication: Fewer ligand-receptor signaling pairs	2. GSVA: Upregulated gene sets in CD8+ T cells (apoptosis, IL2_STAT5, mTORc1) and CD4+ T cells (hypoxia, epithelial-mesenchymal transition) 3. Cell communication: Enhanced FAS_TNFSF6, IFN-γ, CD27_CD70 signaling	exacerbates pulmonary fibrosis 3. Pro-apoptotic signaling drives T cell exhaustion	
Laboratory & Severity Markers	1. P/F ratio <150 (severe ARDS, consistent with non-survival) 2. IL-17 levels: Lower than non-survival group (P<0.05) 3. Shorter ICU/hospital stay	1. P/F ratio <150 (severe ARDS, consistent with survival) 2. IL-17 levels: Significantly elevated (P<0.05 vs. survival) 3. Longer ICU/hospital stay	Elevated IL-17 correlates with pro-inflammatory transcriptome (IL-32, TNF upregulation)	IL-17 + pro-inflammatory gene signature → prolonged ICU stay and mortality
Final Outcome	Hospital survival (100%); no emerging organ failure during ICU stay	Hospital mortality (100%); high incidence of emerging organ failure	Core non-survival transcriptomic signature: CD8+ T cell depletion + Treg overactivation + pro-apoptotic/inflammatory pathway upregulation	This composite transcriptomic signature is a strong predictor of mortality