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RESEARCH ARTICLE

PEDIATRIC EMPYEMA THORACIS: A TWO-YEAR PROSPECTIVE OBSERVATIONAL STUDY OF CLINICAL PROFILE, MICROBIOLOGICAL SPECTRUM, AND SURGICAL OUTCOMES AT A TERTIARY CARE CENTRE IN SOUTH INDIA

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Abstract

Background: Pediatric empyema thoracis is a serious complication of pneumonia that may result in prolonged hospitalization and require invasive pleural interventions. Ultrasonography (USG) provides a practical, radiation-free method for staging pleural disease and may facilitate stage-directed management. This study evaluated the clinical profile, microbiological spectrum, and outcomes of a structured USG-based treatment protocol for pediatric empyema thoracis at a tertiary care centre in South India.

Methods: A prospective observational study was conducted in the Department of General Surgery, Al-Ameen Medical College Hospital, Vijayapura, Karnataka, over a two-year period. Forty-five children below 18 years of age with USG-confirmed empyema thoracis were evaluated. Patients were categorized into three USG stages: Stage 1, free-flowing exudative effusion; Stage 2, fibrinopurulent or loculated disease; and Stage 3, organizing disease with pleural peel and/or lung entrapment. Stage-directed treatment consisted of intercostal drainage (ICD) for Stage 1, ICD with intrapleural streptokinase (IPSK) for Stage 2, and video-assisted thoracoscopic surgery (VATS) or open decortication for Stage 3 disease. Clinical, microbiological, treatment, complication, hospitalization, and three-month radiological outcomes were assessed.

Results: The cohort comprised 29 males (64.4%) and 16 females (35.6%), with the 6–10-year age group being the largest (42.2%). Stage 2 and Stage 3 disease together accounted for 82.2% of patients. Fever (97.8%) and cough (93.3%) were the most common presenting symptoms. Previous pneumonia was the predominant predisposing factor (93.3%), followed by incomplete vaccination (57.8%) and malnutrition (51.1%).

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Pleural fluid culture was positive in 42.2% of patients, with *Staphylococcus aureus* being the most frequent isolate (20.0%). Overall primary treatment success was 91.1% (41/45). Success rates were 75.0% with ICD alone, 90.5% with ICD + IPSK, and 100% with both VATS and open decortication; four patients required salvage treatment. VATS was associated with the shortest mean hospital stay (8.6 days), while the overall weighted mean hospital stay was 12.1 days, and the difference between treatment groups was statistically significant ($p = 0.018$). At three months, complete radiological resolution was achieved in 82.2% of patients, residual pleural thickening in 15.6%, and persistent lung collapse in 2.2%.

Conclusion: Pediatric empyema thoracis frequently presented at an advanced stage in this tertiary-care South Indian population. A structured USG-based, stage-directed treatment protocol was associated with a high overall treatment success rate, a low complication burden, and favourable three-month radiological outcomes. USG appears to be a practical and useful primary tool for staging disease and guiding individualized management, with timely escalation to definitive surgery when indicated.

Abbreviations:-

APSA, American Pediatric Surgical Association; BTS, British Thoracic Society; CAP, community-acquired pneumonia; CT, computed tomography; ET, empyema thoracis; ICD, intercostal drainage; IPFT, intrapleural fibrinolytic therapy; IPSK, intrapleural streptokinase; IV, intravenous; PPE, parapneumonic effusion; USG, ultrasonography; VATS, video-assisted thoracoscopic surgery.

Introduction:-

Community-acquired pneumonia (CAP) remains a formidable challenge to global child health and is a leading cause of morbidity and mortality in children under five years of age, particularly in low- and middle-income countries. While the majority of pneumonia episodes resolve with appropriate antibiotic therapy, a significant subset develops local complications, the most common and serious of which is parapneumonic effusion (PPE) — the accumulation of exudative fluid in the pleural space adjacent to a pneumonic process. A proportion of these effusions become infected and evolve into the more severe condition known as empyema thoracis (ET), characterized by pus in the pleural cavity.

The development of PPE and ET significantly alters the clinical course of pneumonia, leading to prolonged fever, increased hospitalization, a greater requirement for invasive interventions, higher healthcare costs, and considerable morbidity. Despite advances in antibiotic therapy and vaccination programmes, the incidence of pediatric pleural empyema has been reported to be increasing in various parts of the world, including India, making it a persistent and evolving clinical problem.

Empyema thoracis progresses through three pathological stages: (i) the exudative stage, characterized by free-flowing sterile exudate; (ii) the fibrinopurulent stage, marked by bacterial invasion, fibrin deposition, and loculation; and (iii) the organizing stage, in which fibroblasts migrate into the exudate to form a thick, inelastic pleural peel causing lung entrapment. The clinical challenge lies in accurately identifying the stage in order to select the most appropriate management strategy.

Ultrasonography (USG) has emerged as a practical and readily available bedside tool for staging pleural disease in real time without radiation exposure. It characterizes the effusion, identifies septations and loculations, and estimates the degree of pleural thickening — information that is clinically superior to chest radiography for guiding treatment decisions. Guidelines from the American Pediatric Surgical Association (APSA) and the British Thoracic Society (BTS) recommend USG as the primary imaging modality for pediatric parapneumonic effusion, with computed tomography (CT) reserved for complex cases.

Management options span a hierarchy from least to most invasive: antibiotic therapy alone, intercostal drainage (ICD), ICD with intrapleural fibrinolytic therapy (IPFT), video-assisted thoracoscopic surgery (VATS), and open thoracotomy with decortication. The optimal choice is dictated by the USG stage. In resource-limited settings in South India, where a majority of patients present late with advanced disease because of socioeconomic barriers, a structured, USG-guided protocol offers a pragmatic and reproducible framework.

This prospective observational study was designed to (i) analyse the clinical and microbiological profile of pediatric empyema thoracis; (ii) evaluate the outcomes of a structured USG-based staged management protocol; and (iii) assess the utility of USG staging as the primary decision-making tool in a tertiary care setting in South India.

Materials and Methods:-

Study Design and Setting:-

A prospective observational study was conducted in the Department of General Surgery at Al-Ameen Medical College Hospital, Vijayapura, Karnataka, India, a tertiary care referral centre serving a predominantly rural and semi-urban population of North Karnataka. The study was conducted over a two-year period and received ethical clearance from the Institutional Ethics Committee.

Study Population:-

Forty-five consecutive children below 18 years of age diagnosed with empyema thoracis were enrolled after written informed consent was obtained from parents or guardians. Inclusion criteria were (a) age below 18 years; (b) clinical and radiological diagnosis of empyema thoracis confirmed by USG; and (c) written informed consent. Exclusion criteria were recurrent empyema, empyema secondary to malignancy, and patients transferred out before completion of treatment.

USG-Based Staging Protocol:-

All patients underwent thoracic ultrasonography at the time of admission. The USG staging system adopted was as follows:

Stage 1 (exudative): free-flowing, anechoic or minimally echogenic pleural fluid without septations.
Stage 2 (fibrinopurulent/loculated): echogenic pleural fluid with visible fibrin strands, septations, or loculations.
Stage 3 (organizing): thick hyperechoic pleural peel with or without lung entrapment, and non-moving, collapsed lung parenchyma.

CT of the thorax was performed selectively in patients with advanced or complex disease and preoperatively in all patients undergoing open decortication. USG was the primary staging tool for all management decisions.

Treatment Protocol:-

A structured, stage-directed treatment algorithm was applied consistently to all patients.

Stage 1: Intercostal drainage alone. Small-bore chest tubes (12–16 French) were inserted under USG guidance, connected to an underwater seal drainage system, and combined with intravenous antibiotics.
Stage 2: ICD with intrapleural streptokinase (IPSK). Streptokinase (25,000–50,000 IU in 30 mL normal saline) was instilled through the ICD tube, which was clamped for 4 hours and then released. Instillation was repeated daily for three to five doses depending on the clinical and radiological response.
Stage 3: Primary surgical intervention. Cases with an early organizing peel (multiple loculations with early peel) underwent VATS, whereas cases with a thick fibrous peel and lung entrapment underwent open thoracotomy with decortication. Two Stage 3 patients with borderline features were initially trialled on ICD + IPSK; both subsequently required salvage decortication.

Empirical intravenous antibiotics were initiated at admission in all patients and de-escalated on the basis of culture and sensitivity results. Antibiotics were continued for a minimum of 10 days after defervescence.

Outcome Measures:-

Primary treatment success was defined as complete clinical improvement (resolution of fever and respiratory distress) with radiological clearance, without the need for escalation to a more invasive procedure. Secondary outcomes included the need for salvage surgery; complication rates; duration of hospital stay, ICD placement, and intravenous antibiotic therapy; and radiological outcomes (complete resolution, residual pleural thickening, persistent collapse) at three-month follow-up.

Statistical Analysis:-

Data were analysed using SPSS version 23.0 (IBM Corp., Armonk, NY, USA). Categorical variables were expressed as frequencies and percentages. The association between USG stage and treatment modality was assessed using Fisher's exact test. Continuous variables (hospital stay, ICD duration, antibiotic duration) were compared across treatment groups using one-way analysis of variance (ANOVA) with Tukey's honestly significant difference (HSD) post hoc test. A p-value below 0.05 was considered statistically significant.

Results:-

Demographic Profile:-

Table 1. Age and gender distribution of the cohort (n = 45)

Age group (years)	Male, n (%)	Female, n (%)	Total, n (%)
1–5	9 (20.0)	5 (11.1)	14 (31.1)
6–10	13 (28.9)	6 (13.3)	19 (42.2)
11–16	7 (15.6)	5 (11.1)	12 (26.7)
Total	**29 (64.4)**	**16 (35.6)**	**45 (100.0)**

Percentages are calculated from the total cohort (n = 45).

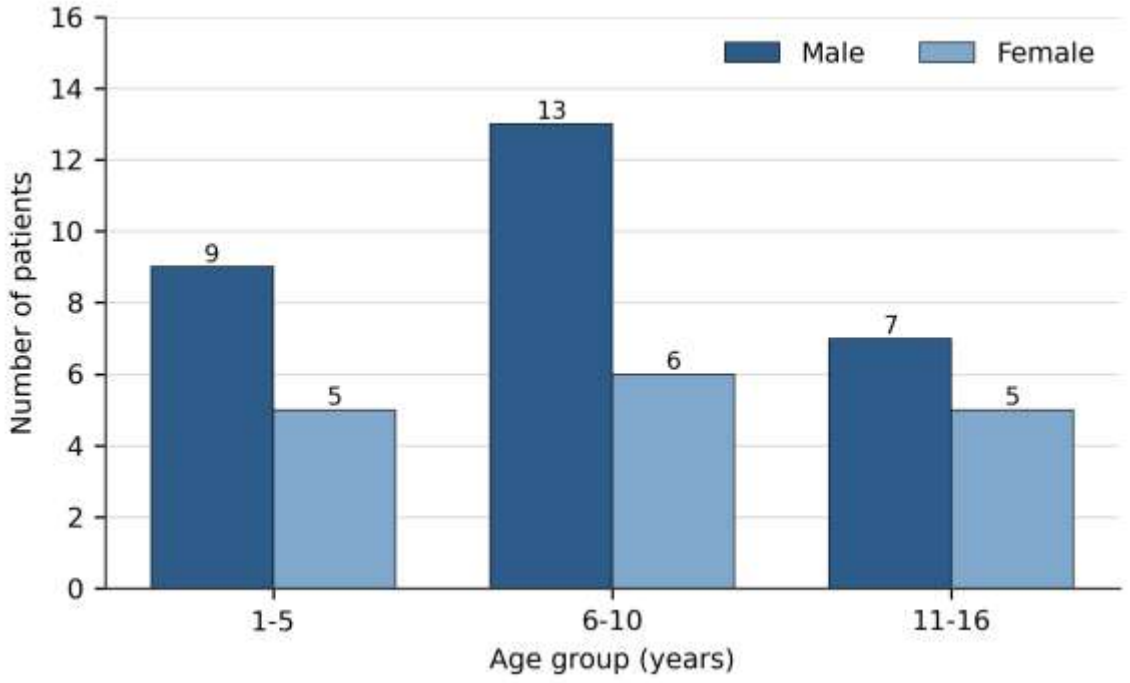

Figure 1. Age and gender distribution of the study cohort (n = 45). Grouped bars show the number of male and female patients in each age band. Empyema affected predominantly school-aged children, with the 6–10-year group accounting for the largest share of the cohort, and males outnumbered females in every age band.

The cohort comprised 45 participants, of whom 29 (64.4%) were male and 16 (35.6%) were female, indicating a male predominance. The 6–10-year age group constituted the largest proportion of the cohort, with 19 participants (42.2%), including 13 males and 6 females. This was followed by the 1–5-year age group, comprising 14 participants (31.1%), with 9 males and 5 females. The 11–16-year age group was the least represented, accounting for 12 participants (26.7%), including 7 males and 5 females. Males outnumbered females across all age groups, with the greatest absolute difference observed in the 6–10-year age group (Table 1, Figure 1).

Ultrasonographic Staging:-

Table 2. Ultrasonographic stage at admission (n = 45)

USG stage	Description	Patients (n)	Percentage (%)
Stage 1	Non-loculated, free-flowing effusion	8	17.8
Stage 2	Loculated, fibrin septations	19	42.2
Stage 3	Organised peel, lung entrapment	18	40.0
Total	—	**45**	**100.0**

USG, ultrasonography.

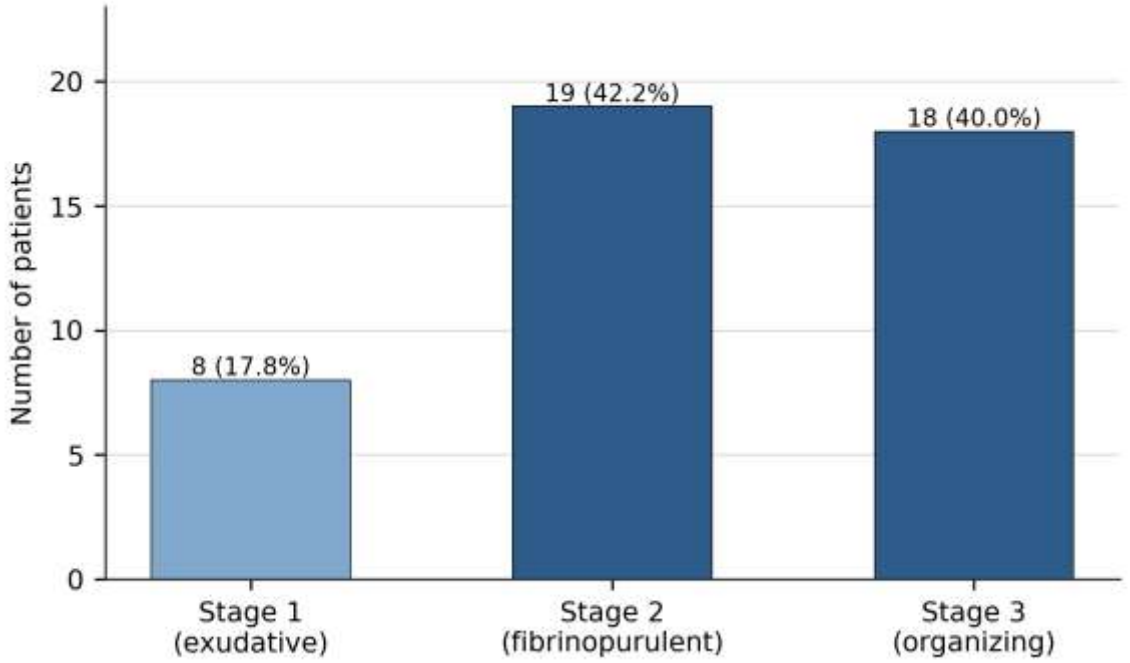

Figure 2. Distribution of patients by ultrasonographic stage at admission (n = 45). Bars show the number and proportion of patients in each USG stage. Advanced disease dominated the presentation profile: fibrinopurulent (Stage 2) and organizing (Stage 3) disease together comprised 82.2% of the cohort, while only 17.8% presented in the free-flowing exudative phase amenable to simple drainage.

Stage 2 and Stage 3 disease predominated, together accounting for 37 of 45 patients (82.2%). Stage 1 was assigned to 8 patients (17.8%), Stage 2 to 19 (42.2%), and Stage 3 to 18 (40.0%) (Table 2, Figure 2).

Clinical Features:-

Table 3. Prevalence of presenting clinical features (n = 45)

Clinical feature	Patients (n)	Percentage (%)
Fever	44	97.8
Cough	42	93.3
Dyspnoea	32	71.1

Clinical feature	Patients (n)	Percentage (%)
Chest pain	13	28.9

Patients could present with more than one clinical feature; percentages therefore do not total 100.

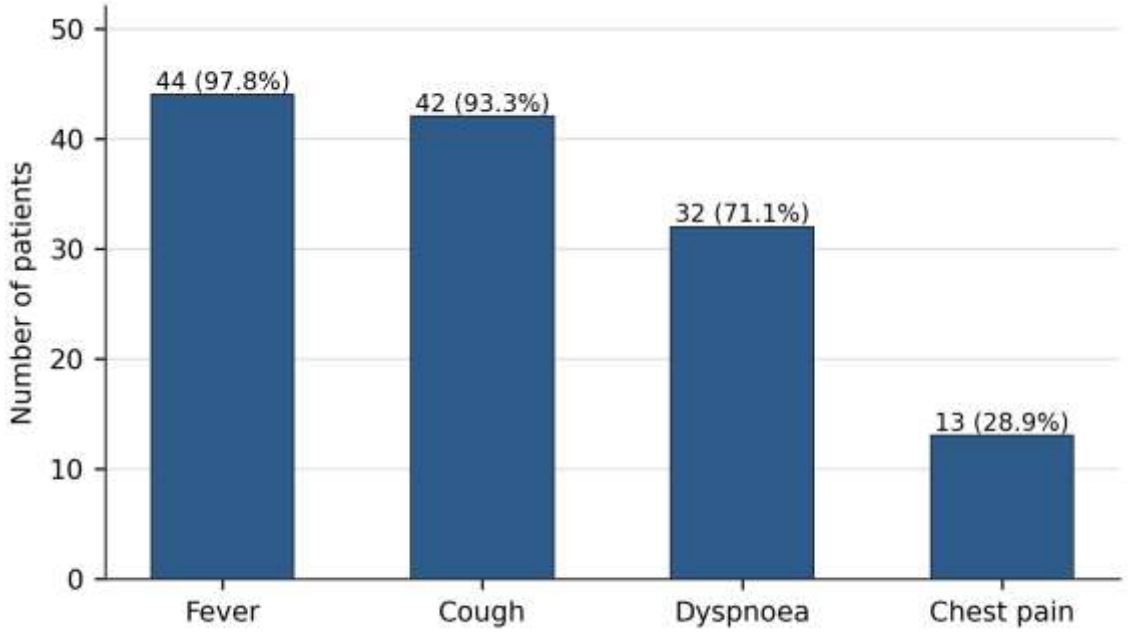

Figure 3. Prevalence of presenting clinical features (n = 45). Bars show the number and percentage of patients reporting each symptom at admission. Fever and cough were near-universal, dyspnoea was present in roughly three-quarters of patients, and chest pain was comparatively infrequent — a pattern consistent with persistent fever and respiratory symptoms being the most useful clinical pointers to complicated pneumonia in children.

Fever was the most common presenting clinical feature, reported in 44 patients (97.8%), followed by cough in 42 patients (93.3%). Dyspnoea was present in 32 patients (71.1%), while chest pain was reported in 13 patients (28.9%). Fever and cough were therefore the predominant presenting symptoms in the study cohort, whereas chest pain was the least frequently reported clinical feature (Table 3, Figure 3).

Predisposing Factors:-

Table 4. Distribution of predisposing factors (n = 45)

Predisposing factor	Patients (n)	Percentage (%)
Previous pneumonia	42	93.3
Incomplete vaccination	26	57.8
Malnutrition	23	51.1
Tuberculosis contact	4	8.9
None identified	3	6.7

More than one predisposing factor could be present in an individual patient; percentages therefore do not total 100.

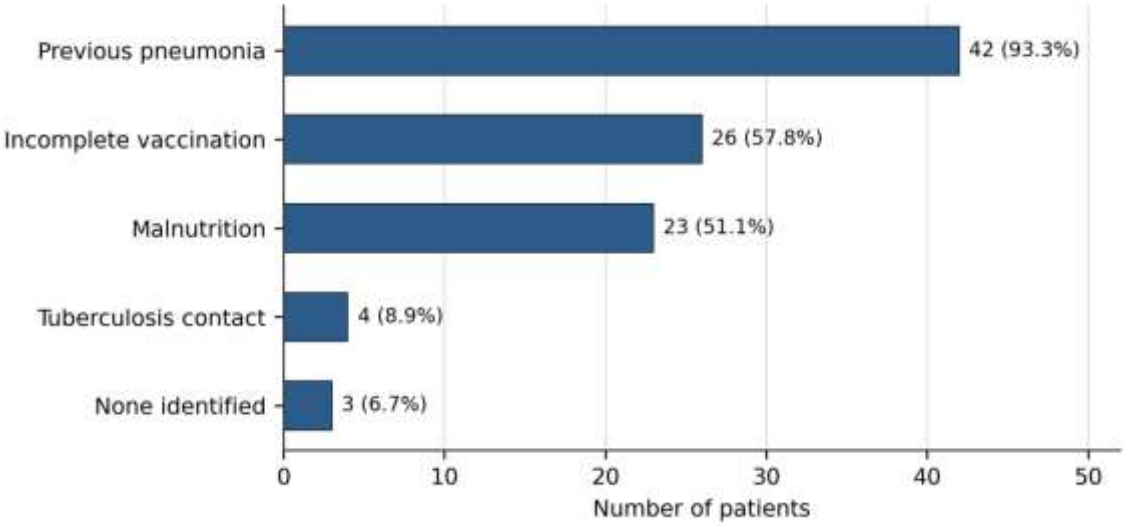

Figure 4. Distribution of predisposing factors (n = 45). Horizontal bars show the number and percentage of patients with each predisposing factor, ordered by frequency. Antecedent pneumonia was almost universal, and the two next most common factors — incomplete immunization and malnutrition — were each present in more than half the cohort, indicating a substantial burden of potentially modifiable risk.

Previous pneumonia was the most frequently identified predisposing factor, reported in 42 patients (93.3%). Incomplete vaccination was observed in 26 patients (57.8%), while malnutrition was present in 23 patients (51.1%). Tuberculosis contact was identified in 4 patients (8.9%), and only 3 patients (6.7%) had no identifiable predisposing factor. Overall, a history of previous pneumonia was the predominant predisposing factor in the study cohort, followed by incomplete vaccination and malnutrition (Table 4, Figure 4).

Microbiological Profile:-

Table 5. Pleural fluid culture results (n = 45)

Culture result	Patients (n)	Percentage (%)
No growth	26	57.8
Staphylococcus aureus	9	20.0
Streptococcus pneumoniae	5	11.1
Klebsiella pneumoniae	4	8.9
Pseudomonas aeruginosa	1	2.2
Total	**45**	**100.0**

Overall culture positivity rate: 42.2% (19/45).

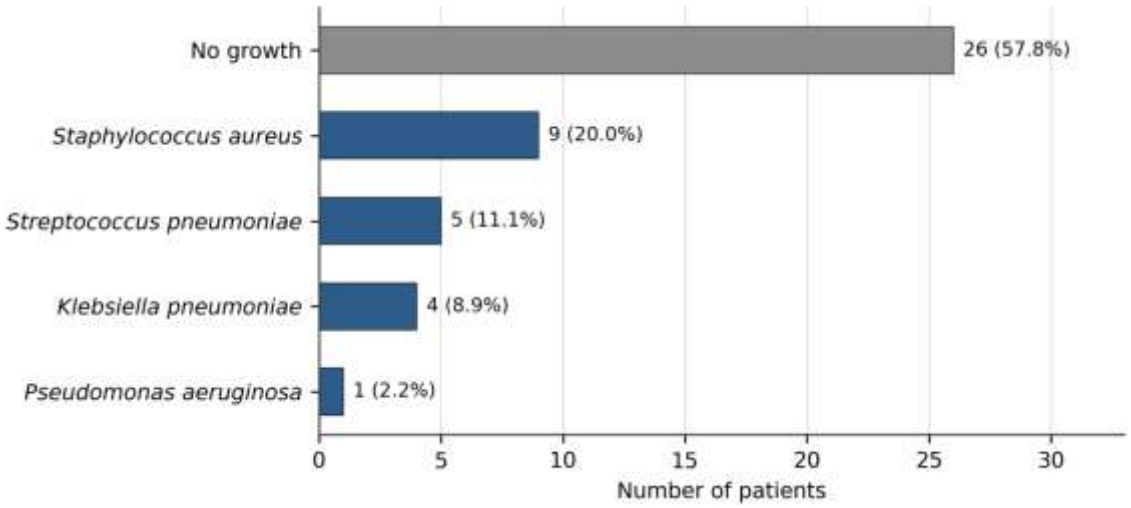

Figure 5. Pleural fluid culture results (n = 45). Horizontal bars show the number and percentage of patients for each culture result. Culture-negative pleural fluid (shown in grey) accounted for the majority of specimens, a finding commonly attributed to prior antibiotic exposure and low bacterial yield; among culture-positive specimens, *S. aureus* was the leading isolate, followed by *S. pneumoniae* and *K. pneumoniae*.

Pleural fluid culture showed no growth in 26 patients (57.8%), making this the most common finding. *Staphylococcus aureus* was isolated in 9 patients (20.0%), followed by *Streptococcus pneumoniae* in 5 patients (11.1%) and *Klebsiella pneumoniae* in 4 patients (8.9%). *Pseudomonas aeruginosa* was the least frequently isolated organism, detected in 1 patient (2.2%). Overall, more than half of the cohort had culture-negative pleural fluid, while among culture-positive cases *S. aureus* was the predominant organism (Table 5, Figure 5).

Treatment Modalities and Outcomes:-

Table 6. Primary treatment modalities employed (n = 45)

Primary treatment	Patients (n)	Percentage (%)
ICD alone	8	17.8
ICD + IPSK	21	46.7
VATS	10	22.2
Open decortication	6	13.3
Total	**45**	**100.0**

ICD, intercostal drainage; IPSK, intrapleural streptokinase; VATS, video-assisted thoracoscopic surgery.

Table 7. Association between ultrasonographic stage and primary treatment (n = 45)

USG stage	ICD alone	ICD + IPSK	VATS	Decortication	Total
Stage 1	8	0	0	0	8
Stage 2	0	19	0	0	19
Stage 3	0	2*	10	6	18
Total	**8**	**21**	**10**	**6**	**45**

**Two Stage 3 patients with borderline ultrasonographic features were initially trialled on ICD + IPSK; both subsequently required salvage decortication. Fisher's exact test, $p < 0.001$. ICD, intercostal drainage; IPSK, intrapleural streptokinase; USG, ultrasonography; VATS, video-assisted thoracoscopic surgery.*

Table 8. Treatment outcomes and need for salvage surgery (n = 45)

Primary treatment	Success (n)	Failure / salvage (n)	Total (n)	Success (%)
ICD alone	6	2	8	75.0
ICD + IPSK	19	2	21	90.5
VATS	10	0	10	100.0
Open decortication	6	0	6	100.0
Overall	**41**	**4**	**45**	**91.1**

Success was defined as complete clinical and radiological resolution without escalation to a more invasive procedure.

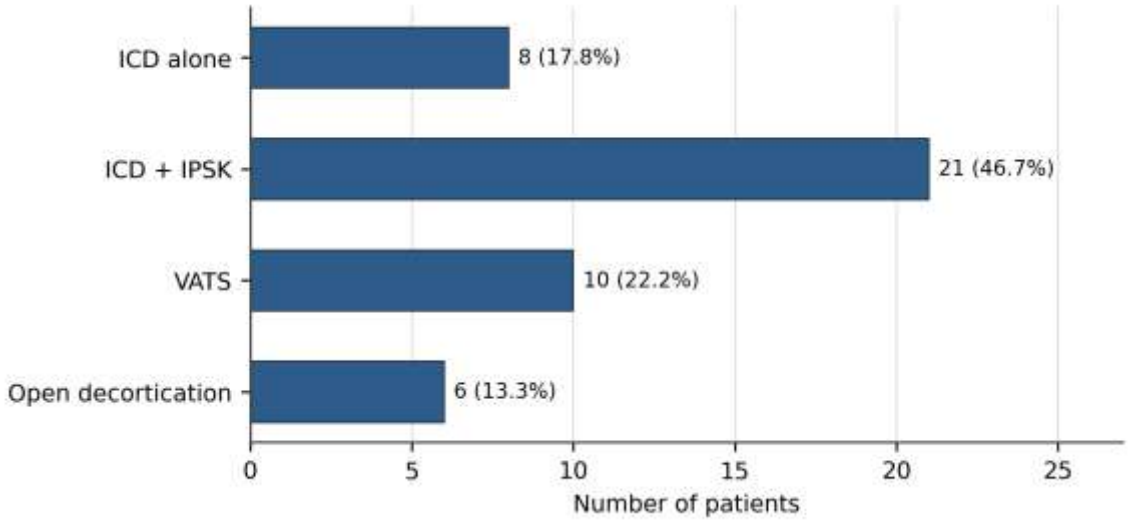

Figure 6. Distribution of primary treatment modalities (n = 45). Horizontal bars show the number and percentage of patients receiving each primary treatment. ICD with intrapleural streptokinase was the single most frequently used modality, reflecting the predominance of Stage 2 loculated disease, while approximately one-third of the cohort required a primary surgical procedure.

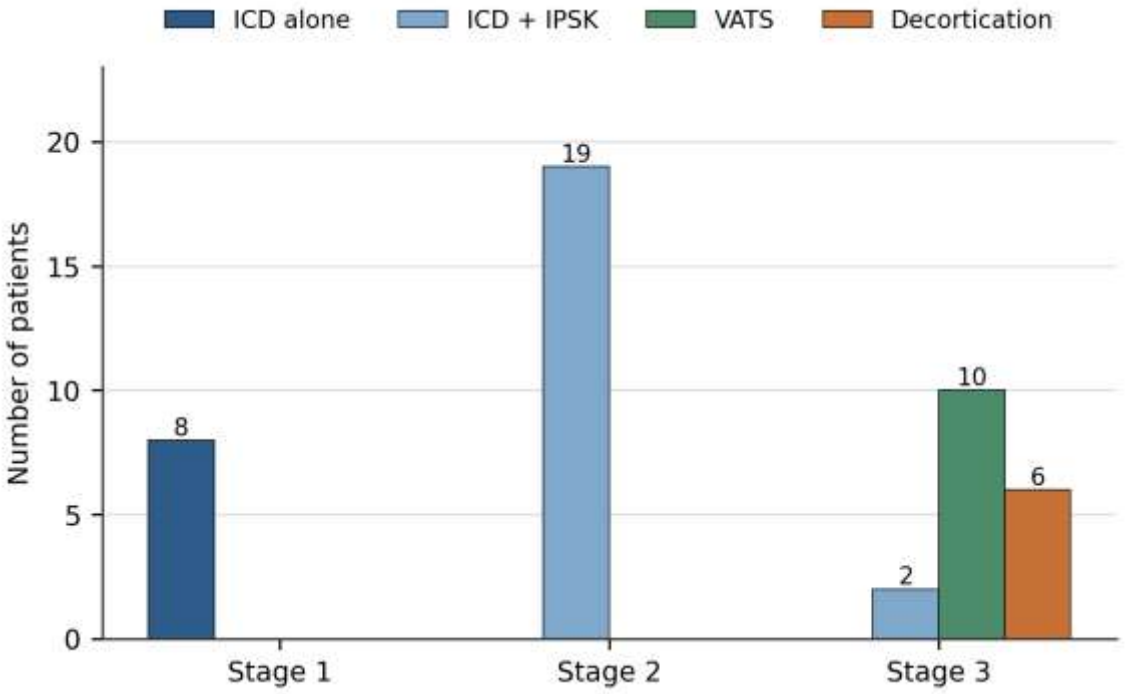

Figure 7. Association between ultrasonographic stage at admission and primary treatment modality (n = 45). Grouped bars show the number of patients receiving each treatment within each USG stage. Treatment allocation tracked the stage closely: Stage 1 disease was managed exclusively with ICD, Stage 2 with ICD plus intrapleural streptokinase, and Stage 3 predominantly with VATS or open decortication. The two Stage 3 patients in the ICD + IPSK column represent borderline cases initially trialled on fibrinolysis, both of whom subsequently required salvage decortication (Fisher's exact test, $p < 0.001$).

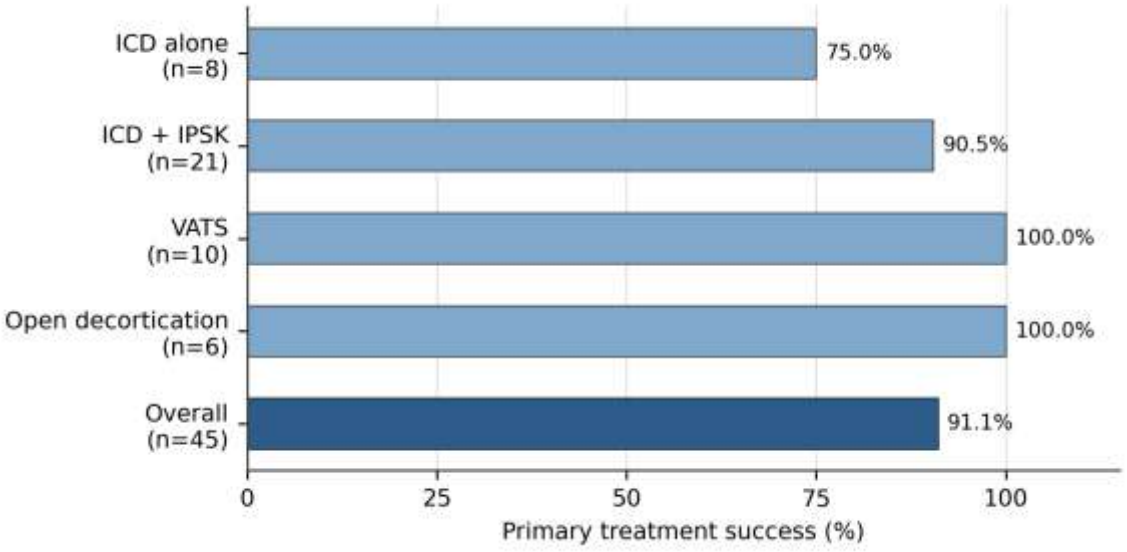

Figure 8. Primary treatment success rate by treatment modality (n = 45). Horizontal bars show the percentage of patients in each treatment group achieving primary success, with the overall cohort result shown in the darker bar at the bottom. Success increased with the definitiveness of the intervention; however, because treatment was allocated by disease stage rather than randomized, these differences reflect stage-directed selection and should not be read as evidence that surgery is universally superior to less invasive treatment.

ICD with IPSK was the most frequently employed primary treatment, used in 21 patients (46.7%), followed by VATS in 10 patients (22.2%), ICD alone in 8 patients (17.8%), and open decortication in 6 patients (13.3%) (Table 6, Figure 6). Treatment allocation followed the USG stage closely: all Stage 1 patients were managed with ICD alone, all Stage 2 patients with ICD + IPSK, and Stage 3 patients predominantly with VATS or open decortication (Table 7, Figure 7).

The overall primary treatment success rate was 91.1% (41/45 patients). VATS and open decortication demonstrated the highest success rates, at 100.0% in both groups. Treatment with ICD + IPSK was successful in 19 of 21 patients (90.5%), while ICD alone achieved success in 6 of 8 patients (75.0%). Four patients in total required salvage treatment, with the highest proportion of treatment failures occurring among those initially managed with ICD alone (Table 8, Figure 8).

Complications:-

Table 9. Complications encountered (n = 45)

Complication	Episodes / patients (n)	Percentage (%)
Tube blockage	4	8.9
Subcutaneous emphysema	4	8.9
Persistent air leak	1	2.2
Surgical site infection	1	2.2
Uncomplicated course	35	77.8

No procedure-related mortality was recorded in the cohort.

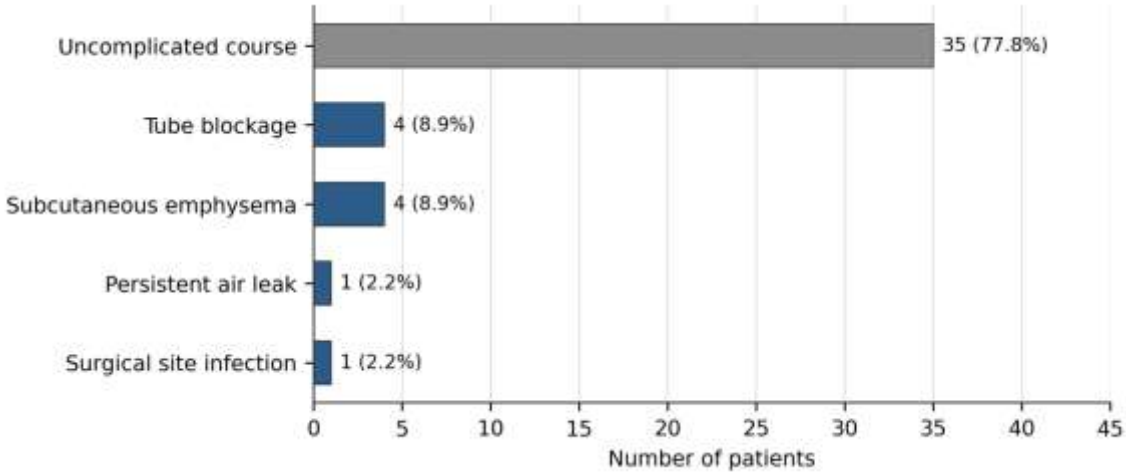

Figure 9. Complications encountered during treatment (n = 45). Horizontal bars show the number and percentage of patients experiencing each complication, with the uncomplicated course shown in grey for reference. Just over three-quarters of patients had no complication, and the events that did occur were predominantly minor drainage-related problems rather than major procedure-related morbidity.

The majority of patients (35, 77.8%) had an uncomplicated clinical course. Tube blockage and subcutaneous emphysema were the most frequently encountered complications, each occurring in 4 patients (8.9%). Persistent air leak and surgical site infection were observed in 1 patient each (2.2%). Overall, complications were relatively uncommon (Table 9, Figure 9).

Duration of Hospital Stay, Drainage, and Intravenous Antibiotic Therapy:-

Table 10. Mean duration of hospital stay, intercostal drainage, and intravenous antibiotic therapy by treatment modality (n = 45)

Primary treatment	Hospital stay (days)	ICD in situ (days)	IV antibiotics (days)
ICD alone	16.0	13.0	15.6
ICD + IPSK	11.7	8.8	11.3
VATS	8.6	6.9	11.2
Open decortication	14.3	9.4	13.5
Overall weighted mean	**12.1**	**9.2**	**12.3**

One-way ANOVA for hospital stay across treatment groups: p = 0.018. ICD, intercostal drainage; IPSK, intrapleural streptokinase; IV, intravenous; VATS, video-assisted thoracoscopic surgery.

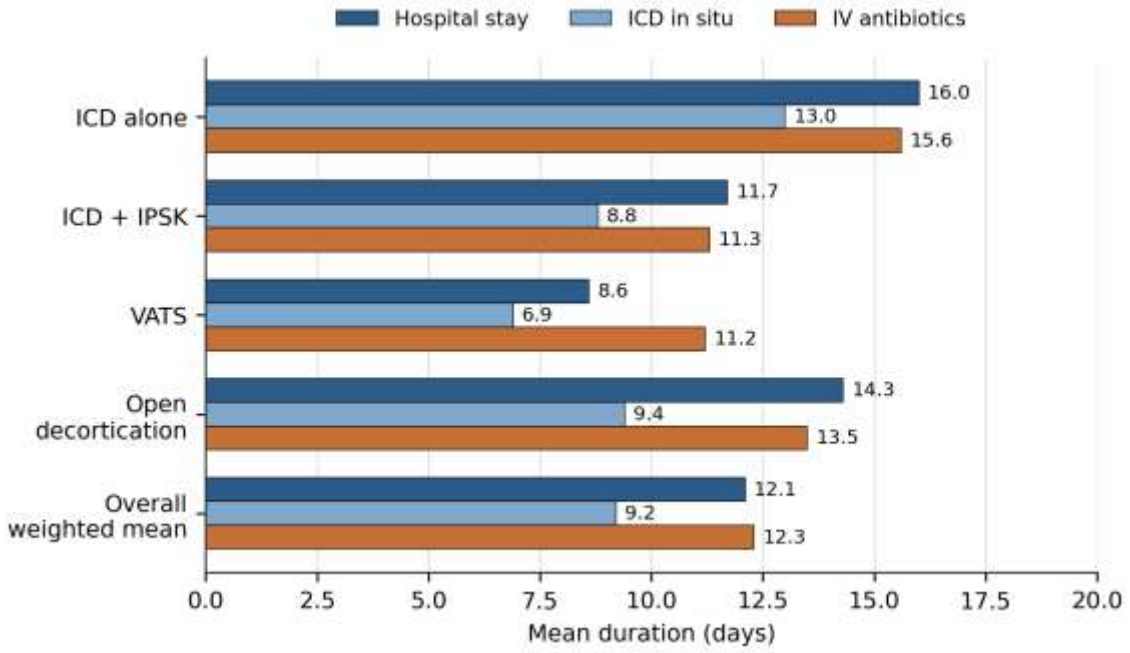

Figure 10. Mean duration of hospital stay, intercostal drainage in situ, and intravenous antibiotic therapy by treatment modality (n = 45). Grouped horizontal bars compare the three duration measures across treatment groups, with the overall weighted means shown at the bottom for reference. VATS was associated with the shortest hospitalization and the shortest period of pleural drainage, whereas ICD alone was associated with the longest; the longer stay in the open decortication group is likely to reflect greater baseline disease severity and chronicity rather than a disadvantage inherent to the operation.

A clear gradient was observed across treatment groups. The VATS group had the shortest mean hospital stay (8.6 days), followed by ICD + IPSK (11.7 days), open decortication (14.3 days), and ICD alone (16.0 days); the overall weighted mean hospital stay was 12.1 days. One-way ANOVA revealed a statistically significant difference in mean hospital stay across treatment groups ($p = 0.018$). Post hoc analysis (Tukey's HSD) demonstrated that the VATS group had a significantly shorter hospital stay than the ICD-only group ($p = 0.018$) and the ICD + IPSK group ($p = 0.042$). Mean duration of ICD placement and intravenous antibiotic therapy followed a similar pattern, with overall weighted means of 9.2 days and 12.3 days respectively (Table 10, Figure 10).

Radiological Outcomes at Three Months:-

Table 11. Radiological outcome at three months by initially allocated treatment (n = 45)

Initial treatment	Complete resolution	Residual thickening	Persistent collapse	Total
ICD alone	8	0	0	8
ICD + IPSK	18	3	0	21
VATS	10	0	0	10
Open decortication	1	4	1	6
Total	**37 (82.2%)**	**7 (15.6%)**	**1 (2.2%)**	**45**

Outcomes are reported according to the initially allocated treatment (intention-to-treat), irrespective of subsequent salvage procedures.

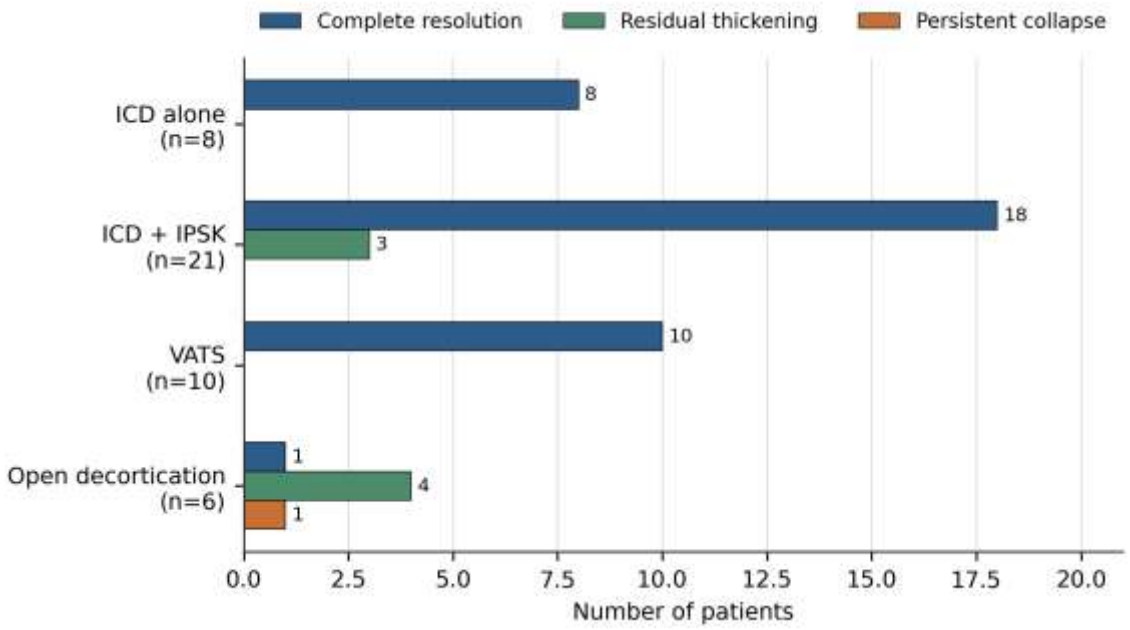

Figure 11. Radiological outcome at three months by initially allocated treatment (n = 45). Grouped horizontal bars show the number of patients achieving complete resolution, residual pleural thickening, or persistent lung collapse within each initial treatment group. Complete resolution was the dominant outcome overall; the concentration of residual thickening in the open decortication group reflects the thick fibrous peel and lung entrapment that indicated that procedure in the first place, and persistent collapse was confined to a single patient.

At three-month radiological follow-up, complete resolution was observed in 37 patients (82.2%), making it the most frequent outcome. Complete resolution was achieved in all 8 patients treated with ICD alone and in all 10 patients who underwent VATS. In the ICD + IPSK group, 18 of 21 patients achieved complete resolution, while 3 had residual pleural thickening. Among the 6 patients who underwent open decortication, 1 achieved complete resolution, 4 had residual pleural thickening, and 1 had persistent lung collapse. Overall, 7 patients (15.6%) demonstrated residual pleural thickening and 1 patient (2.2%) had persistent collapse at three months (Table 11, Figure 11).

Discussion:-

Pediatric empyema thoracis remains an important complication of community-acquired pneumonia and is associated with prolonged illness, increased hospitalization, and the need for invasive pleural interventions. The present prospective observational study evaluated the clinical profile, microbiological spectrum, and outcomes of a structured USG-based, stage-directed treatment protocol in children with empyema thoracis at a tertiary care centre in South India. The principal findings were a predominance of advanced-stage disease at presentation, a high frequency of culture-negative pleural fluid, Staphylococcus aureus as the leading identifiable pathogen, and an overall primary treatment success rate of 91.1%. The results also demonstrate that USG staging can provide a practical framework for selecting the intensity of intervention according to the pathological stage of empyema.

In the present cohort, males constituted 64.4% of patients, giving a male-to-female ratio of approximately 1.8:1. The 6–10-year age group represented the largest proportion of patients (42.2%), followed by the 1–5-year group (31.1%) and the 11–16-year group (26.7%). This demographic distribution indicates that pediatric empyema in the present setting affected predominantly school-aged children, although all pediatric age groups were represented. The male predominance observed in this study is consistent with the pattern reported in several clinical series of pediatric empyema, although the precise reasons for this difference remain uncertain.

A particularly important finding was the predominance of advanced disease at admission. Stage 2 and Stage 3 disease together accounted for 82.2% of the cohort, while only 17.8% presented with Stage 1 disease. This pattern is clinically relevant in a tertiary referral centre serving predominantly rural and semi-urban populations, where delayed presentation may allow a parapneumonic effusion to progress from a free-flowing exudative collection to a fibrinopurulent or organizing phase. The high proportion of advanced disease emphasizes the importance of early recognition and referral of children with pneumonia who develop persistent fever, respiratory distress, or pleural symptoms.

Fever and cough were the predominant clinical manifestations, occurring in 97.8% and 93.3% of patients respectively. Dyspnoea was reported in 71.1%, whereas chest pain was less frequent, occurring in 28.9%. These findings reinforce the importance of persistent fever and respiratory symptoms as clinical indicators of complicated pneumonia and possible pleural infection in children. The high frequency of fever in the cohort also reflects the infectious nature of empyema and the substantial inflammatory burden associated with advanced pleural disease.

Previous pneumonia was the most frequent predisposing factor, identified in 93.3% of patients. Incomplete vaccination was present in 57.8%, while malnutrition was documented in 51.1%. These findings highlight the close relationship between pediatric empyema and antecedent pneumonia, and suggest that preventable factors such as incomplete immunization and nutritional compromise may contribute to disease severity. The presence of tuberculosis contact in 8.9% of patients also reflects the relevance of tuberculosis exposure in the regional clinical context, although the present study was primarily concerned with post-pneumonic empyema.

Pleural fluid culture was positive in 42.2% of patients, while 57.8% showed no bacterial growth. Culture-negative empyema is common in pediatric practice and may be related to prior antibiotic exposure, low bacterial burden, difficulty in obtaining an adequate specimen, or limitations of conventional culture techniques. Among culture-positive cases, Staphylococcus aureus was the predominant organism, accounting for 20.0% of the entire cohort, followed by Streptococcus pneumoniae (11.1%), Klebsiella pneumoniae (8.9%), and Pseudomonas aeruginosa (2.2%). The predominance of S. aureus in the present study is clinically important because it supports the need for empirical antimicrobial coverage directed against common bacterial pathogens while allowing subsequent de-escalation according to culture and sensitivity results.

The most important methodological feature of the present study was the use of thoracic USG as the primary staging and treatment decision-making tool. USG permitted differentiation between free-flowing effusion, fibrinous septations and loculations, and organizing pleural peel with lung entrapment. This approach enabled treatment to be matched to the underlying stage of disease: Stage 1 patients were managed with intercostal drainage and antibiotics, Stage 2 patients received ICD with intrapleural streptokinase, and advanced Stage 3 disease was managed primarily by VATS or open decortication according to the extent of organization and lung entrapment. The protocol thus avoided applying a single treatment modality uniformly to all patients.

The overall primary treatment success rate was 91.1%, with 41 of 45 patients achieving successful primary treatment. Success was 75.0% with ICD alone, 90.5% with ICD plus intrapleural streptokinase, and 100% in both

the VATS and open decortication groups. The higher success rates observed with definitive surgical procedures should, however, be interpreted in the context of stage-directed treatment. VATS and open decortication were preferentially used in patients with advanced disease, and these results should therefore not be interpreted as evidence that surgery is universally superior to less invasive treatment. Rather, the findings suggest that treatment appropriately selected according to disease stage can achieve high overall success while reserving more invasive procedures for patients with organized or refractory disease.

Four patients required salvage treatment. Two patients initially treated with ICD alone required escalation, while two Stage 3 patients who underwent an initial trial of ICD plus intrapleural streptokinase subsequently required salvage decortication. These cases illustrate an important practical aspect of stage-directed management: fibrinolytic therapy can be useful in selected loculated disease but may be insufficient once a mature organizing peel and significant lung entrapment have developed. Early recognition of treatment failure and timely escalation are therefore essential to prevent prolonged sepsis, persistent pleural restriction, and delayed lung re-expansion.

The duration of hospitalization also varied according to treatment modality. VATS was associated with the shortest mean hospital stay, at approximately 8.6 days, followed by ICD plus IPSK at 11.7 days, open decortication at 14.3 days, and ICD alone at 16.0 days. The overall weighted mean hospital stay was 12.1 days. There was a statistically significant difference in hospital stay between treatment groups ($p = 0.018$), with post hoc analysis demonstrating significantly shorter hospitalization in the VATS group compared with ICD alone and ICD plus IPSK. These findings suggest that, in appropriately selected patients with advanced disease, early definitive surgical clearance may facilitate faster clinical recovery and reduce the duration of hospitalization. Nevertheless, the longer stay associated with open decortication may reflect the greater severity and chronicity of disease in patients requiring this procedure rather than an inherent disadvantage of the operation.

The duration of ICD placement and intravenous antibiotic therapy showed a similar pattern. The overall weighted mean duration of ICD placement was 9.2 days and that of intravenous antibiotic therapy was 12.3 days. VATS was associated with the shortest mean duration of ICD placement (6.9 days), whereas ICD alone had the longest (13.0 days). These findings further support the concept that effective source control and restoration of lung expansion can shorten the period of pleural drainage and facilitate recovery.

The complication rate was relatively low, with 35 patients (77.8%) experiencing an uncomplicated clinical course. Tube blockage and subcutaneous emphysema were the most common complications, each occurring in 8.9% of patients, while persistent air leak and surgical site infection occurred in 2.2% each. No major pattern of procedure-related morbidity was identified. The relatively low complication burden suggests that stage-directed management can be performed safely when supported by appropriate imaging, drainage, antibiotic therapy, and timely surgical intervention.

The three-month radiological follow-up provided additional evidence of favourable outcomes. Complete radiological resolution was observed in 37 patients (82.2%), while 7 patients (15.6%) had residual pleural thickening and only 1 patient (2.2%) had persistent lung collapse. Complete resolution was documented in all patients initially treated with ICD alone and all patients treated with VATS, while 18 of 21 patients treated with ICD plus IPSK achieved complete resolution. In the open decortication group, residual pleural thickening was more frequent. This finding should again be interpreted in relation to baseline disease severity, as open decortication was undertaken in patients with a thick fibrous peel and lung entrapment. Importantly, persistent collapse at three months was uncommon.

The findings of this study support the practical value of USG as the primary bedside imaging modality for pediatric empyema thoracis. USG is non-invasive, avoids radiation exposure, can be repeated serially, and provides real-time information regarding septations, loculations, pleural thickening, and lung entrapment. In resource-constrained settings, a USG-based protocol may therefore offer an accessible and reproducible method for stratifying disease and selecting treatment, with CT reserved for complex cases and for preoperative planning in patients requiring open decortication.

The principal strength of the present study is its prospective evaluation of a structured, stage-directed treatment pathway in a real-world tertiary-care setting. The protocol integrated clinical assessment, USG staging, microbiological evaluation, antibiotic therapy, drainage, fibrinolysis, and surgery according to disease severity. Overall, the study indicates that pediatric empyema thoracis in this South Indian population frequently presents in

advanced stages, and that a structured USG-based staging system allows treatment to be tailored to disease severity with a high overall success rate, a relatively low complication burden, and favourable three-month radiological outcomes.

Limitations:-

Several limitations should be considered when interpreting these findings. First, the study was conducted at a single centre and included a relatively small cohort (n = 45), which limits generalizability. Second, treatment was not randomized; allocation was determined by USG stage, creating an inherent risk of selection bias and confounding by indication, so between-group comparisons of success rate and hospital stay reflect differences in baseline disease severity as well as in treatment. Third, referral bias may have contributed to the high proportion of advanced disease, since the institution is a tertiary referral centre. Fourth, follow-up was limited to three months, and objective pulmonary function assessment was not performed, so longer-term functional outcomes are unknown. Larger multicentre prospective studies with standardized long-term follow-up and comparative evaluation of different treatment strategies are required to validate these findings.

Conclusion:-

Pediatric empyema thoracis in this tertiary-care South Indian cohort was characterized by a high proportion of advanced-stage disease, with Stage 2 and Stage 3 empyema accounting for 82.2% of cases. Fever and cough were the predominant presenting symptoms, previous pneumonia was the most frequent predisposing factor, and *Staphylococcus aureus* was the commonest organism isolated from culture-positive pleural fluid. A structured ultrasonography-based staging protocol enabled treatment to be tailored according to disease severity, ranging from intercostal drainage and fibrinolytic therapy to VATS and open decortication. Overall primary treatment success was 91.1%, with VATS demonstrating a particularly favourable recovery profile and the shortest hospital stay among the treatment groups. At three months, 82.2% of patients demonstrated complete radiological resolution, with persistent collapse occurring in only 2.2%. These findings support USG as a practical and valuable primary tool for staging pediatric empyema and guiding stage-directed treatment. Early recognition of advanced disease, appropriate escalation of therapy, and timely surgical intervention when indicated may improve clinical and radiological outcomes. Multicentre studies with larger cohorts and longer follow-up are warranted to further validate this management strategy.

Declarations:-

Ethical approval and consent to participate: The study was approved by the Institutional Ethics Committee of Al-Ameen Medical College, Vijayapura *[insert approval number and date]*, and was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from the parents or legal guardians of all participating children.

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