



SYSTEMATIC REVIEW

Perinatal Outcomes of Pleuro-Amniotic Shunting in Isolated Pleural Effusions: Systematic Review and Meta-analysis

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ABSTRACT

Introduction: Pleuro-amniotic shunting has been proposed for fetal pleural effusion, although its safety and efficacy remain uncertain. Therefore, we aimed to evaluate the perinatal outcomes of the fetal therapy for isolated pleural effusion through a systematic review and single-arm meta-analysis.

Methods: PubMed/MEDLINE, Embase, Scopus, and Cochrane Central were searched for studies reporting outcomes of fetuses undergoing pleuro-amniotic shunting for isolated pleural effusion. The primary outcomes were overall survival and resolution of fetal hydrops. Single-arm

random-effects meta-analyses were performed to estimate pooled event rates with 95% confidence intervals (CI).

Results: Ten retrospective cohort studies comprising 416 fetuses treated with pleuro-amniotic shunting were included. The pooled overall survival rate was 65.36% (95% CI 59.46–70.83; $I^2=30.7\%$). Resolution of fetal hydrops occurred in 62.25% of cases (95% CI 54.27–69.62; $I^2=0\%$). A total of 62 catheter displacements were recorded, corresponding to a combined prevalence of 17.13% (95% CI 13.59–21.36). Overall, there were 155 preterm births, resulting in a pooled prevalence of 69.67% (95% CI 61.24–76.95; $I^2=26.9\%$). Preterm premature rupture

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of membranes (PPROM) prevalence was 17.65% (95% CI 7.78–35.28; $I^2=84.5\%$; $p<0.001$).

Conclusion: Pleuro-amniotic shunting achieves overall survival in approximately two-thirds of treated fetuses and resolving fetal hydrops in most cases. However, the procedure may be associated with preterm birth and PROM, underscoring the need for multidisciplinary perinatal management. Although the evidence is limited, these findings support pleuro-amniotic shunting as a promising treatment for progressive isolated fetal pleural effusion and highlight the need for prospective studies to optimize patient selection and perinatal care.

Keywords: Fetus; Pleuro-amniotic shunting; Pleural effusion; Perinatal outcomes; Systematic review

Key Summary Points

Why carry out this study?

Pleuro-amniotic shunting has been proposed for fetal pleural effusion, although its safety and efficacy remain uncertain.

PubMed/MEDLINE, Embase, Scopus, and Cochrane Central were searched for studies reporting outcomes of fetuses undergoing pleuro-amniotic shunting for isolated pleural effusion.

What was learned from the study?

The overall survival, resolution of hydrops, catheter displacement, preterm births, and preterm premature rupture of membranes were, respectively, 65.36%, 62.25%, 17.13%, 69.67%, and 17.65%.

Although the evidence is limited, these findings support pleuro-amniotic shunting as a promising treatment for progressive isolated fetal pleural effusion.

INTRODUCTION

Fetal pleural effusion is defined as the accumulation of fluid within the pleural space. In neonates, pleural effusion is classified as chylothorax when the pleural fluid contains triglyceride levels >1.1 mmol/L and $>80\%$ lymphocytes [1]. This condition is rare, with an estimated incidence of 1 in 10,000 to 1 in 15,000 pregnancies. It may occur as an isolated (primary) condition or in association with other disorders (secondary) [2]. Secondary causes include chromosomal abnormalities, genetic syndromes, obstructive uropathy, lymphatic disorders (e.g., Noonan syndrome), congenital lymphatic malformations, thoracic cavity anomalies, Rh or ABO incompatibility, nonimmune fetal hydrops, congenital infections, congenital heart defects, metabolic disorders, and hematologic disorders [3, 4].

Pleural effusion occupies the pleural space, causing compression of the lungs, which may result in pulmonary hypoplasia. Hydrops develops secondary to cardiac compression and the resulting reduction in cardiac output. Polyhydramnios may occur because mediastinal shift compresses the esophagus, leading to impaired fetal swallowing [5]. Prenatal diagnosis can be established as early as the second trimester by ultrasonographic visualization of an anechoic fluid collection within one or both hemithoraces. The clinical course is variable, ranging from spontaneous resolution to progression to hydrops, polyhydramnios, preterm birth, and fetal death [6, 7].

Treatment in utero for an isolated pleural effusion has been proposed to prevent progression to hydrops [8, 9]. One proposed treatment is thoracentesis, which involves inserting a 20-gauge needle into the pleural cavity and aspirating the fluid. While this is a simple procedure, the fluid accumulates rapidly again, requiring repeated procedures and increasing the risk of infection or preterm premature rupture of membranes (PPROM). The standard treatment for isolated pleural effusion is pleuro-amniotic shunting. This procedure involves inserting a 9F trocar (outer diameter 3 mm) under continuous ultrasound guidance. A double-coiled pigtail silicone

catheter is then placed through the trocar to connect the pleural space to the amniotic cavity [10, 11]. However, preterm delivery, PPRM, and catheter displacement pleuro-amniotic shunting have been reported in association with pleuro-amniotic shunting [12–14]. Other complications reported with the procedure include premature placental abruption, traumatic hemothorax, and rib fractures [15, 16]. Nevertheless, pleuro-amniotic shunting has proven to be an effective technique for resolving primary pleural effusion, even in hydropic fetuses, with an overall survival rate above 75% and low rates of postnatal neurological sequelae [17].

Despite the potential benefits of pleuro-amniotic shunting in reversing hydrops and improving postnatal survival, uncertainties remain regarding actual rates of perinatal complications. Therefore, we aimed to conduct a systematic review and meta-analysis assessing the perinatal outcomes of pleuro-amniotic shunts in cases of isolated pleural effusion.

METHODS

Study Design

This systematic review was conducted according to the PRISMA-P (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols) guidelines. The review strictly adhered to the established guidelines, ensuring transparency and reproducibility of the adopted procedures. Additionally, the protocol was registered with the Prospective Register of Systematic Reviews (PROSPERO) under the number CRD420251241549.

Information Sources

PubMed, Embase, Scopus, and Cochrane Central databases were systematically searched after PROSPERO registration. Two authors conducted the systematic review. Any disagreements were resolved through a discussion panel facilitated by a third author. The study selection process involved an initial screening of titles and

abstracts, followed by an evaluation of the full text of potentially eligible studies.

Eligibility Criteria

We included observational studies (retrospective cohorts) in which (1) fetuses underwent pleuro-amniotic shunting; (2) due to unilateral or bilateral pleural effusion; (3) at any gestational age; (4) regardless of hydrops; and (5) exhibiting presumably isolated pleural effusion (no other detected structural or chromosomal abnormalities). The following were excluded: (1) studies without the prespecified outcomes of interest (overall survival, resolution of fetal hydrops, catheter displacement, preterm birth, PPRM, or chorioamnionitis); (2) overlapping populations, defined as studies with overlapping institutions and recruitment periods; (3) retracted articles; (4) case reports and case series with fewer than five participants; (5) non-English studies.

Outcomes

The primary outcomes of this review were overall survival, defined as the newborn survival until discharge, and resolution of fetal hydrops (frequency of hydrops before and after the intervention). Catheter displacement, preterm birth (before 37 weeks of gestational age), PPRM (before 37 weeks of gestational age), and chorioamnionitis were assessed as secondary outcomes.

Data Extraction

Two reviewers applied the eligibility criteria independently and selected studies for inclusion without knowing each other's decisions. After completing this process, the authors compared their results and resolved any disagreements by consulting a third author. The Rayyan software [18] (<http://rayyan.qcri.org/>) was used to record the selected studies and decisions regarding inclusion or exclusion. Two authors independently extracted the following information from each study using Excel 2010 spreadsheets (Microsoft Corp., Redmond, WA, USA): (1) sample size, (2) number of events related to the pre-specified outcomes, (3) demographic data, and

(4) prospective registration of clinical trials. The extracted data were then reviewed twice independently by all authors and compared. Additional review sessions were conducted in the event of any discrepancies in the data.

The search terms “fetal pleural effusion” and “pleuroamniotic shunts” were used in combination with keywords linked by the Boolean operators AND and OR (Table 1). First, the titles and abstracts were reviewed, and the selected studies were downloaded from each platform as csv files. The files were then imported and analyzed using the Rayyan software to assess the articles’ eligibility. After duplicates were removed, those studies that were eligible underwent a detailed evaluation in accordance with the eligibility criteria.

Summary of Results

The information collected from the studies included in this review was summarized in Excel® 2010 (Microsoft Corp., Redmond, WA, USA). This included details from the publications, such as the year of publication, the study design, the sample size, the study location and the objectives, as well as information related to the outcomes. The main conclusions of the selected articles were also included.

Bias Analysis

Two reviewers conducted an independent assessment of the study across seven domains: (1) pre-intervention (confounding factors and participant selection); (2) during the intervention (intervention classification); and (3) post-intervention (deviations from intended interventions, missing data, outcome measurement and reported results selection). The Risk of Bias in Non-Randomized Studies of Interventions (ROBINS-I) tool [19] was used to assess the cohort studies. On the basis of these analytical criteria, the studies were categorized as “low risk of bias”, “moderate risk”, “serious risk”, or “critical risk”. The overall assessment of each article was determined by the highest level of risk identified in any of its individual domains,

in accordance with the principle of the most conservative scenario.

Data Synthesis and Meta-analysis

We conducted a single-arm meta-analysis using a random-effects model. The results were presented as pooled prevalence estimates with their corresponding 95% confidence intervals (CI). To assess statistical heterogeneity, we used Cochran’s *Q* test and the I^2 statistic. We classified I^2 values of <40%, 40–75%, and >75% as representing low, moderate, and high heterogeneity, respectively. The meta-analysis was performed using the meta package in RStudio, version 4.2.2 (R Foundation for Statistical Computing, Vienna, Austria), using the metaprop function for pooling prevalence estimates.

RESULTS

A total of 847 studies, including unpublished articles and abstracts, were identified through searches of the PubMed/MEDLINE, Embase, Scopus, and Cochrane Central databases. After 477 duplicates were removed, 370 studies remained for screening of titles and abstracts. Of these, 17 were selected for a full-text review. Ultimately, ten studies met the inclusion criteria and were included in our systematic review and meta-analysis (Fig. 1).

Characteristics of Included Studies

The characteristics of the included studies are summarized in Table 2. Ten retrospective cohort studies, published between 1988 and 2022, were included [9, 13, 20–27]. These studies encompassed 587 fetuses, of whom 416 underwent thoraco-amniotic shunting. The studies were conducted in Europe, North America, South America, Asia, and Oceania. The weighted mean gestational age at the time of intervention was 28.1 weeks. Overall, 68.3% (284/416) of fetuses were male and 31.7% (132/416) were female. Bilateral pleural effusions were predominant, accounting for 76.9% (320/416) of cases, while unilateral effusions accounted for 23.1%

Table 1 Applied search strategy

Database	Search
PubMed/MEDLINE	(“Pleural Effusion”[Mesh] OR “pleural effusion*”[tiab] OR “fetal pleural effusion*”[tiab] OR “fetal hydrothorax”[tiab] OR “fetal hydrothoraces”[tiab] OR “fetal thoracic effusion*”[tiab] OR “fetal chest effusion*”[tiab] OR “fetal pleural fluid”[tiab]) AND (“pleuroamniotic shunt*”[tiab] OR “pleuro-amniotic shunt*”[tiab] OR “thoracoamniotic shunt*”[tiab] OR “thoraco-amniotic shunt*”[tiab] OR “thoracopleural shunt*”[tiab] OR “pleural-amniotic shunt*”[tiab] OR “amniotic shunt*”[tiab])
Embase	(‘pleural effusion’/exp OR ‘pleural effusion’:ti,ab OR ‘fetal pleural effusion’:ti,ab OR ‘fetal hydrothorax’:ti,ab OR ‘fetal hydrothoraces’:ti,ab OR ‘fetal thoracic effusion’:ti,ab OR ‘fetal chest effusion’:ti,ab OR ‘fetal pleural fluid’:ti,ab) AND (‘pleuroamniotic shunt’:ti,ab OR ‘pleuro-amniotic shunt’:ti,ab OR ‘thoracoamniotic shunt’:ti,ab OR ‘thoraco-amniotic shunt’:ti,ab OR ‘thoracopleural shunt’:ti,ab OR ‘pleural-amniotic shunt’:ti,ab OR ‘amniotic shunt’:ti,ab)
SCOPUS	(‘pleural effusion’/exp OR ‘pleural effusion’:ti,ab OR ‘fetal pleural effusion’:ti,ab OR ‘fetal hydrothorax’:ti,ab OR ‘fetal hydrothoraces’:ti,ab OR ‘fetal thoracic effusion’:ti,ab OR ‘fetal chest effusion’:ti,ab OR ‘fetal pleural fluid’:ti,ab) AND (‘pleuroamniotic shunt’:ti,ab OR ‘pleuro-amniotic shunt’:ti,ab OR ‘thoracoamniotic shunt’:ti,ab OR ‘thoraco-amniotic shunt’:ti,ab OR ‘thoracopleural shunt’:ti,ab OR ‘pleural-amniotic shunt’:ti,ab OR ‘amniotic shunt’:ti,ab)
Cochrane central	#1 MeSH descriptor: [Pleural Effusion] explode all trees #2 (“pleural effusion*” OR “fetal pleural effusion*” OR “fetal hydrothorax” OR “fetal hydrothoraces” OR “fetal thoracic effusion*” OR “fetal chest effusion*” OR “fetal pleural fluid”):ti,ab,kw #3 #1 OR #2 #4 (“pleuroamniotic shunt*” OR “pleuro-amniotic shunt*” OR “thoracoamniotic shunt*” OR “thoraco-amniotic shunt*” OR “thoracopleural shunt*” OR “pleural-amniotic shunt*” OR “amniotic shunt*”):ti,ab,kw #5 #3 AND #4

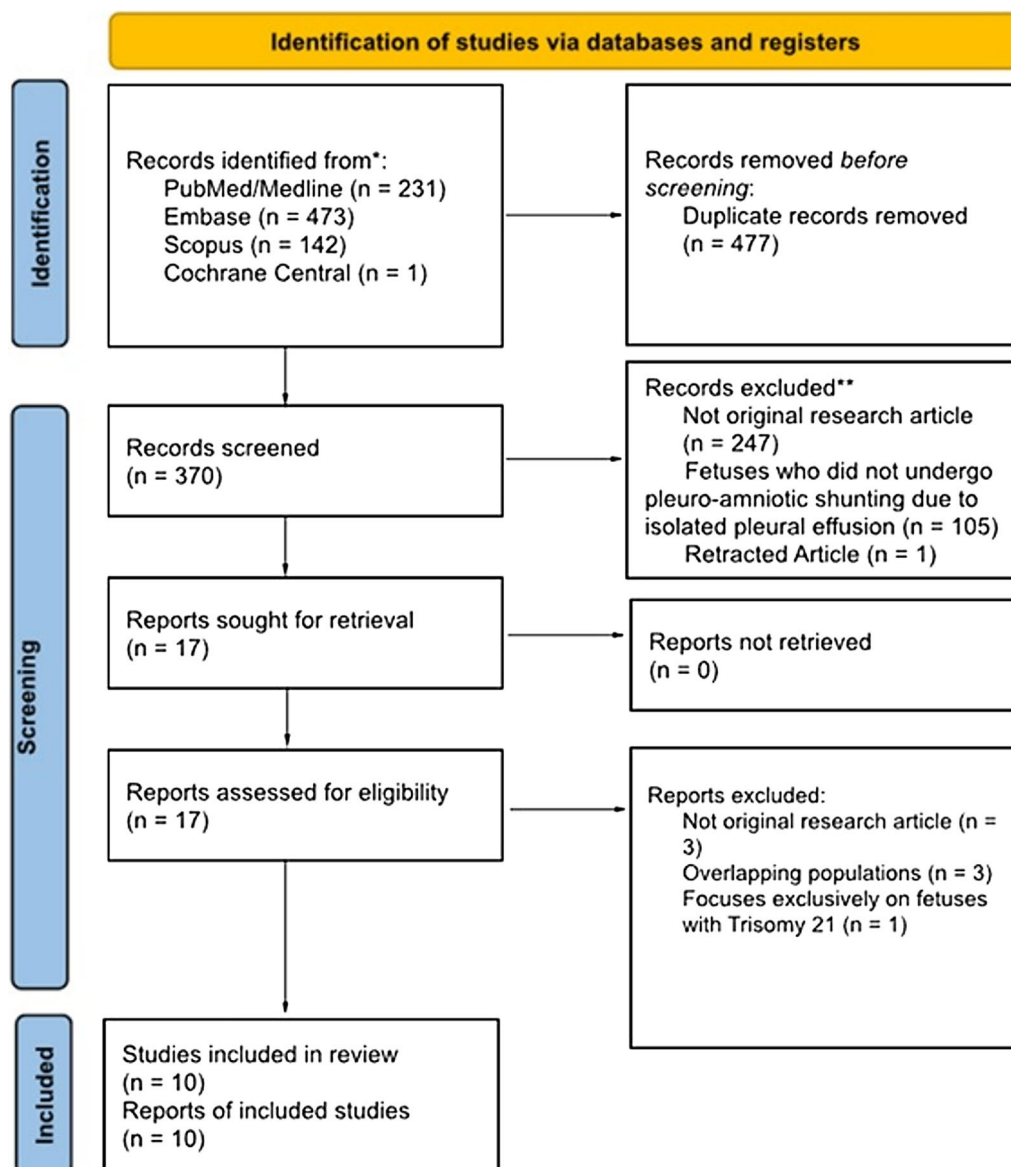


Fig. 1 PRISMA flowchart

(96/416). Primary outcomes included overall survival, and reversal of hydrops. Secondary outcomes included catheter displacement, preterm birth, PPRM, and chorioamnionitis.

Risk of Bias

The methodological quality of the included studies was assessed using the ROBINS-I tool (Figs. 2, 3). All studies were considered to have

an overall moderate risk of bias. This classification was determined exclusively by the “confounding factors” domain, which was assessed as having a moderate risk in all studies due to the retrospective, observational nature of the available evidence, and the potential influence of unmeasured confounding factors. All other ROBINS-I domains, including participant selection, intervention classification, deviations from intended interventions, missing data, outcome measurement, and selective reporting,

Table 2 Baseline characteristics, study design, and main outcomes of the studies included in the systematic review of thoracoamniotic shunting for isolated fetal pleural effusion

Author (year)	Country	Study period	Study design	Total group	Intervention group	Mean GA at intervention (±SD)	Mean GA at diagnosis (±SD)	Mean GA at delivery (±SD)	Sex (%)	Unilateral vs bilateral pleural effusion	Hydrops in diagnosis (nc %)	Follow-up (months)	Primary outcomes	Secondary outcomes	Key findings
Grandt et al. (2022)	Germany	2014–2020	Retrospective cohort, single center	39 fetuses	39 (all subject to TAS)	27.4 weeks (mean) [range 27.4; range 19–33 weeks]	26.6 weeks (mean) [range 19–32 weeks]	33.6 weeks (mean) [range 23–41 weeks]	Male: 69.2% (27/39) Female: 30.8% (12/39)	Unilateral: 25.6% (10/39) Bilateral: 74.4% (29/39)	51.3% (20/39)	Assessment of survival and complications up to neonatal period (hospital discharge)	Overall survival rate of 74.4% (29/39); live birth rate of 97.4% (38/39); resolution of prenatal hydrops in 65.0% (13/20) of hydropic cases	High postnatal ventilatory support required in 88.0% (of live births); catheter displacement/migration success rate and results in excellent in neonatal survival 5.1% (2/39); chorioamnionitis in 2.6% (1/39). Presence of genetic anomalies (trisomy 21 and Noonan syndrome) in 23.1% (9/39)	Thoracoamniotic shunt with Sonarex® brand drain has high technical success rate and results in excellent neonatal survival rates, comparable to traditional drains
Suyama et al. (2018)	Japan	2004–2016	Retrospective cohort, single center	41 fetuses	41 (all with primary pleural effusion and associated hydrops)	28.5 weeks (median) [range 19.3–33.8 weeks]	28.1 weeks (median) [range 19.1–33.7 weeks]	33.7 weeks (median) [range 22.1–40.3 weeks]	Male: 65.9% (27/41) Female: 34.1% (14/41)	Unilateral: 4.9% (2/41) Bilateral: 95.1% (39/41)	100% (41/41)	Up to 28 days postpartum (neonatal period)	Overall survival up to 28 days: 46.4% (19/41); IUTD: 26.8% (11/41); neonatal death: 26.8% (11/41)	Displacement/migration of the drain in 24.4% (10/41); need for shunt reinjection in 12.2% (5/41). PROM and preterm birth (< 37 weeks) in 82.9% (24/29 of live births)	In hydropic fetuses with pleural effusion, fetal lung size measured by ultrasound (LTR) after shunt placement is a direct and reliable predictor of postnatal survival

Table 2 continued

Author (year)	Country	Study period	Study design	Total group	Intervention group	Mean GA at intervention (±SD)	Mean GA at diagnosis (±SD)	Mean GA at delivery (±SD)	Sex (%)	Unilateral vs bilateral pleural effusion	Hydrops in diagnosis (n= %)	Follow-up (months)	Primary outcomes	Secondary outcomes	Key findings
Chon et al. (2019)	USA	2006–2016	Retro-spective cohort, single center	29 fetuses	29 (all with dominant pleural effusion and secondary hydrops)	27.6 weeks (median) [range 20.3–36.9 weeks]	27.1 weeks (median) [range 20.0–36.4 weeks]	35.7 weeks (median) [range 25.4–41.0 weeks]	Male: 69.0% (20/29) Female: 31.0% (9/29)	Unilateral: 31.0% (9/29) Bilateral: 69.0% (20/29)	100% (29/29)	Median of 39 months (3 years and 3 months) [range 9 months–7.5 years]	Overall survival rate of 72.4% (21/29); resolution of hydrops in the prenatal setting in 58.6% (17/29); complete postnatal resolution of effusion in 100% of the 21 survivors	90.5% (19/21) of survivors required NICU admission for a median of 15 days. Prenatal hydrops in the catheter displacement rate was 10.3% (3/29). Complications such as PROM occurred in 13.8% (4/29). No severe long-term neurocognitive delay was observed in the survivor sample	Shunt surgery in cases of hydrops secondary to effusion confers an excellent survival rate (72%). Although it requires immediate neonatal intensive care, the vast majority of children do not present with respiratory sequelae or severe morbidities in the long-term follow-up

Table 2 continued

Author (year)	Country	Study period	Study design	Total group	Intervention group	Mean GA at intervention ($\pm$ SD)	Mean GA at diagnosis ($\pm$ SD)	Mean GA at delivery ($\pm$ SD)	Sex (%)	Unilateral vs bilateral pleural effusion	Hydrops in diagnosis (ne-%)	Follow-up (months)	Primary outcomes	Secondary outcomes	Key findings
Ruano et al. (2011)	Brazil	2005–2009	Retro-spective cohort	56 fetuses	10 (only 10 fetuses with isolated effusion/Group I underwent TAS)	29.1 $\pm$ 3.2 weeks (mean)	25.6 $\pm$ 4.3 weeks (mean)	34.2 $\pm$ 3.5 weeks (mean)	Male: 60.0% (6/10) Female: 40.0% (4/10)	Unilateral: 20.0% (2/10) Bilateral: 80.0% (8/10)	70.0% (7/10)	Until neonatal hospital discharge	Overall survival of the shunt sub-group was 70.0% (7/10). In the general hydropic group, mortality was higher, but the shunt tended to improve the survival of the isolates	Preterm delivery (< 37 weeks) in 70.0% (7/10) of shunt cases; catheter displacement/migration rate of 20.0% (2/10); PROM in 10.0% (1/10)	Fetal pleural effusion associated with hydrops fetalis and structural/chromosomal malformations has a very poor prognosis. In cases of isolated and large pleural effusion, prenatal intervention with TAS offers a satisfactory perinatal survival rate (70%)

Table 2 continued

Author (year)	Country	Study period	Study design	Total group	Intervention group	Mean GA at intervention (±SD)	Mean GA at diagnosis (±SD)	Mean GA at delivery (±SD)	Sex (%)	Unilateral vs bilateral pleural effusion	Hydrops in diagnosis (n, %)	Follow-up (months)	Primary outcomes	Secondary outcomes	Key findings
Jeong et al. (2015)	South Korea	1999–2012	Retro-spective cohort, single center	65 fetuses (3 lost to follow-up, total: 68 pregnancies analyzed)	65 (all submitted to TAS with double-basket type catheter)	28.3 weeks (median) [range 18.5–34.1 weeks]	27.9 weeks (median) [range 17.4–34.0 weeks]	33.6 weeks (median) [range 26.2–40.0 weeks]	Male: 73.8% (48/65) Female: 26.2% (17/65)	Unilateral: 13.8% (9/65) Bilateral: 86.2% (56/65)	76.9% (50/65)	Perinatal assessment up to hospital discharge	Overall survival rate of 64.6% (42/65). Survival rate was significantly higher in group without hydrops (93.3%, 14/15) than in group with hydrops (56.0%, 28/50). Resolution of post-shunt hydrops in 58.0% (29/50)	IUFD of 3.1% (2/65); neonatal death of 32.3% (21/65). Preterm delivery occurs in 57.1% of cases. Drain displacement/migration in 18.5% (12/65)	Presence of fetal hydrops is mainly negative prognostic factor for survival after shunt placement. However, successful resolution of hydrops in the intrauterine environment after catheter insertion reverses this scenario, and is strongly associated with postnatal survival

Table 2 continued

Author (year)	Country	Study period	Study design	Total group	Intervention group	Mean GA at intervention (±SD)	Mean GA at diagnosis (±SD)	Mean GA at delivery (±SD)	Sex (%)	Unilateral vs bilateral pleural effusion	Hydrops in diagnosis (n= %)	Follow-up (months)	Primary outcomes	Secondary outcomes	Key findings
Burnett et al. (2024)	USA	2010–2022	Retrospective genetic screening cohort	114 fetuses	57 (fetuses with normal/negative karyotype/microarray who underwent TAS)	26.1 ± 3.8 weeks (mean)	25.2 ± 4.1 weeks (mean)	34.1 ± 3.9 weeks (mean)	Male: 66.7% (38/57) Female: 33.3% (19/57)	Unilateral: 21.1% (12/57) Bilateral: 78.9% (45/57)	63.2% (36/57)	Neonatal follow-up until final outcome of discharge or death	Overall survival was 75.4% (43/57) in genetically normal group that underwent shunting. Survival was higher in unilateral fetuses with normal genetics than in bilateral fetuses	Prolapse rate of 12.3% (7/57); chorioamnionitis in 3.5% (2/57). Catheter displacement/migration requiring re-intervention or thoracentesis in 15.8% (9/57)	Fetuses with bilateral pleural effusion have significantly higher risk of underlying genetic abnormality malities (such as Noonan syndrome and aneuploidies) compared to those with unilateral effusion. When genetics are normal/negative, management with TAS achieves excellent survival rates (> 75%)

Table 2 continued

Author (year)	Country	Study period	Study design	Total group	Intervention group	Mean GA at intervention (±SD)	Mean GA at diagnosis (±SD)	Mean GA at delivery (±SD)	Sex (%)	Unilateral vs bilateral pleural effusion	Hydrops in diagnosis (n, %)	Follow-up (months)	Primary outcomes	Secondary outcomes	Key findings
Petersen et al. (2013)	Australia	2001–2011	Retrospective cohort, tertiary center	45 fetuses	24 fetuses	27.9 weeks (mean) [range 20.2–34.1 weeks]	26.4 weeks (mean) [range 19.0–33.5 weeks]	33.1 weeks (mean) [range 26.0–39.4 weeks]	Male: 70.8% (17/24) Female: 29.2% (7/24)	Unilateral: 16.7% (4/24) Bilateral: 83.3% (20/24)	58.3% (14/24)	Assessment of neonatal period until discharge	Overall survival to hospital discharge was 62.5% (15/24) in shunt arm.	IUFD of 12.5% (3/24); neonatal death of 25.0% (6/24). Catheter displacement/migration documented in 20.8% (5/24) of cases.	TAS should be reserved for cases with evidence of significant mediastinal compression and progression of effusion. In these severe cases, fetal therapy can rescue more than 60% of fetuses, stabilizing survival rates even in presence of hydrops fetalis

Table 2 continued

Author (year)	Country	Study period	Study design	Total group	Intervention group	Mean GA at intervention (± SD)	Mean GA at diagnosis (± SD)	Mean GA at delivery (± SD)	Sex (%)	Unilateral vs bilateral pleural effusion	Hydrops in diagnosis (ne-%)	Follow-up (months)	Primary outcomes	Secondary outcomes	Key findings
Walsh et al. (2011)	Ireland	2002–2010	Retro-spective cohort	12 fetuses with severe pleural effusion	12 (all underwent TAS with Harrison catheter)	29.1 weeks (mean) [range 20.4–34.0 weeks]	28.3 weeks (mean) [range 19.0–33.6 weeks]	33.8 weeks (mean) [range 29.4–38.4 weeks]	Male: 58.3% (7/12) Female: 41.7% (5/12)	Unilateral: 16.7% (2/12) Bilateral: 83.3% (10/12)	58.3% (7/12)	Neonatal period until hospital discharge	Overall survival was 58.3% (7/12). Survival was 42.8% (3/7) in sub-group with hydrops and 80.0% (4/5) in sub-group without hydrops	Drain displacement/migration rate of 25.0% (3/12). Pre-term birth (< 37 weeks) occurred in 71.4% of live births. PROM rate of 16.7% (2/12)	TAS is effective in reversing risk of pulmonary hypoplasia secondary to large effusions. Early diagnosis and absence of fetal hydrops are associated with considerably higher perinatal survival rates

Table 2 continued

Author (year)	Country	Study period	Study design	Total group	Intervention group	Mean GA at intervention ($\pm$ SD)	Mean GA at diagnosis ($\pm$ SD)	Mean GA at delivery ($\pm$ SD)	Sex (%)	Unilateral vs bilateral pleural effusion	Hydrops in diagnosis (n, %)	Follow-up (months)	Primary outcomes	Secondary outcomes	Key findings
Picone et al. (2004)	France	1988–2002	Retro-spective cohort	54 fetuses	54 (all eligible cases were treated with TAS immediately after diagnosis)	29.6 $\pm$ 3.6 weeks (mean)	29.4 $\pm$ 3.6 weeks (mean)	34.2 $\pm$ 3.2 weeks (mean)	Male: 66.7% (36/54) Female: 33.3% (18/54)	Unilateral: 24.1% (13/54) Bilateral: 75.9% (41/54)	100% (54/54)	Neonatal assessment up to discharge	Overall survival rate of 57.4% (31/54); IUFD of 16.7% (9/54); neonatal death of 13.0% (7/54); medical terminations of pregnancy 13.0% (7/54)	Premature delivery occurred in 71.1% (27/38 of pregnancies that continued); PROM in 18.4% (7/38); chorioamnionitis in 10.5% (4/38). There were no reports of severe drain migration in this series	TAS represents a valid aggressive therapeutic strategy that achieves 100% technical success rates in insertion and saves more than half of fetuses with severely compromised prognosis due to secondary hydrops

Table 2 continued

Author (year)	Country	Study period	Study design	Total group	Intervention group	Mean GA at intervention ($\pm$ SD)	Mean GA at diagnosis ($\pm$ SD)	Mean GA at delivery ($\pm$ SD)	Sex (%)	Unilateral vs bilateral pleural effusion (ne-%)	Hydrops in diagnosis	Follow-up (months)	Primary outcomes	Secondary outcomes	Key findings
Kelly et al. (2021)	Canada	1991–2014	Retrospective cohort	132 pregnancies underwent TAS at the institution	85 (surgical mapping restricted only to fetuses with isolated/primary pleural effusion, excluding 47 cases that were secondary to congenital pulmonary anomalies)	28.2 $\pm$ 4.1 weeks (mean)	27.6 $\pm$ 4.3 weeks (mean)	34.0 $\pm$ 4.0 weeks (mean)	Male: 68.2% (58/85) Female: 31.8% (27/85)	Unilateral: 61.2% (33/85) Bilateral: 61.2% (52/85)	61.2% (52/85)	Median of 24 months (2 years) postpartum	Overall survival of isolated subgroup was 68.2% (58/85). Survival was significantly higher in fetuses without hydrops (23/33, 69.7%) and in hydropic fetuses that reversed the condition after shunt (35/52, 67.3%).	Preterm delivery rate (<37 weeks) was high at 75.3% (64/85); PROM documented in 15.3% (13/85). Intrauterine and drainage complications remain high, long-term neurological and respiratory functional prognosis for survivors is decidedly favorable	TAS for isolated effusions confers robust long-term survival rate. Although risks associated with prematurity and drainage complications remain high, long-term neurological and respiratory functional prognosis for survivors is decidedly favorable

GA gestational age, SD standard deviation, TAS thoracoamniotic shunt, PROM preterm premature rupture of membranes, NICU neonatal intensive care unit, IUFD intrauterine fetal death, LTR lung-to-thorax transverse area ratio

		Risk of bias domains							
		D1	D2	D3	D4	D5	D6	D7	Overall
Study	Grandt et al. (2022)	<div>-</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>-</div>
	Suyama et al. (2018)	<div>-</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>-</div>
	Chon et al. (2019)	<div>-</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>-</div>
	Ruano et al. (2011)	<div>-</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>-</div>
	Jeong et al. (2015)	<div>-</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>-</div>
	Burnett et al. (2024)	<div>-</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>-</div>
	Petersen et al. (2013)	<div>-</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>-</div>
	Walsh et al. (2011)	<div>-</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>-</div>
	Picone et al. (2004)	<div>-</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>-</div>
	Kelly et al. (2021)	<div>-</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>+</div>	<div>-</div>

Domains:

D1: Bias due to confounding.

D2: Bias due to selection of participants.

D3: Bias in classification of interventions.

D4: Bias due to deviations from intended interventions.

D5: Bias due to missing data.

D6: Bias in measurement of outcomes.

D7: Bias in selection of the reported result.

Judgement

-

Moderate

+

Low

Fig. 2 Risk of bias of included studies

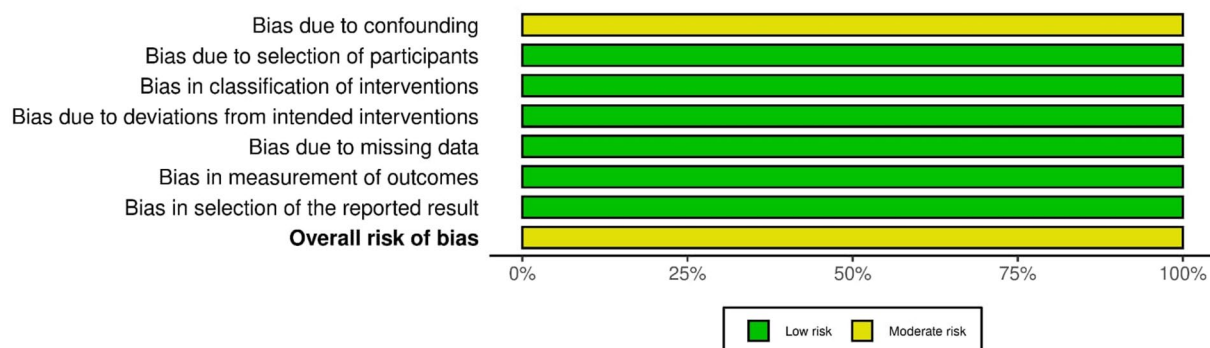


Fig. 3 Bar chart of risk of bias

were consistently assessed as having a low risk of bias.

Meta-analysis

The analysis of overall survival included ten studies and 416 fetuses, of whom 272 survived. The pooled estimate indicated an overall survival rate of 65.36% (95% CI 59.46–70.83). Survival rates ranged from 46.34% to 75.44%, demonstrating reasonable consistency among the results from different centers, with low heterogeneity ($I^2=30.7\%$; $p=0.164$) (Fig. 4).

Four studies involving 151 fetuses contributed to the analysis regarding the resolution of hydrops. Resolution was observed in 94 cases, corresponding to a pooled prevalence of 62.25% (95% CI 54.27–69.62). The individual rates remained relatively homogeneous, ranging

from 58.0% to 67.3%. This finding was corroborated by the absence of statistical heterogeneity ($I^2=0\%$), which indicates excellent agreement among the studies (Fig. 5).

Drain displacement was reported in nine studies involving 362 fetuses. A total of 62 episodes were recorded, corresponding to a combined prevalence of 17.13% (95% CI 13.59–21.36). The observed frequencies ranged from 10.34% to 25.00%, with no evidence of heterogeneity ($I^2=0\%$; $p=0.854$), indicating high consistency among the analyzed studies (Fig. 6).

The outcome of preterm birth was investigated in six studies, involving 224 fetuses. Overall, there were 155 preterm births, resulting in a pooled prevalence of 69.67% (95% CI 61.24–76.95). Despite the high frequency of this event, variability among the studies was limited ($I^2=26.9\%$; $p=0.232$), with individual estimates ranging from 56.9% to 79.0% (Fig. 7).

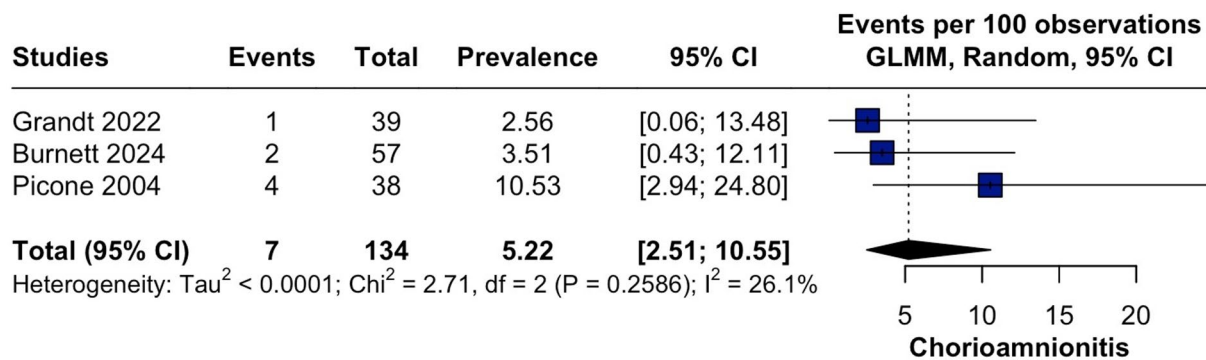


Fig. 4 Forest plot of overall survival

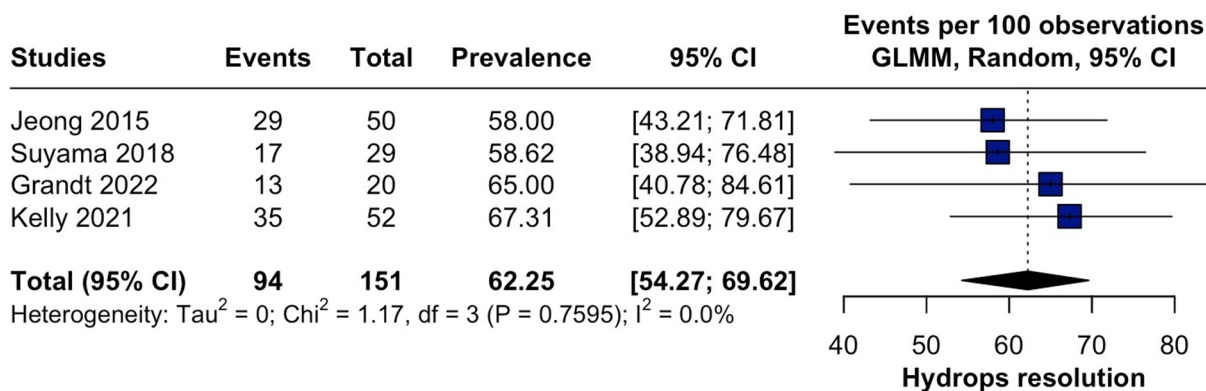


Fig. 5 Forest plot of hydrops resolution

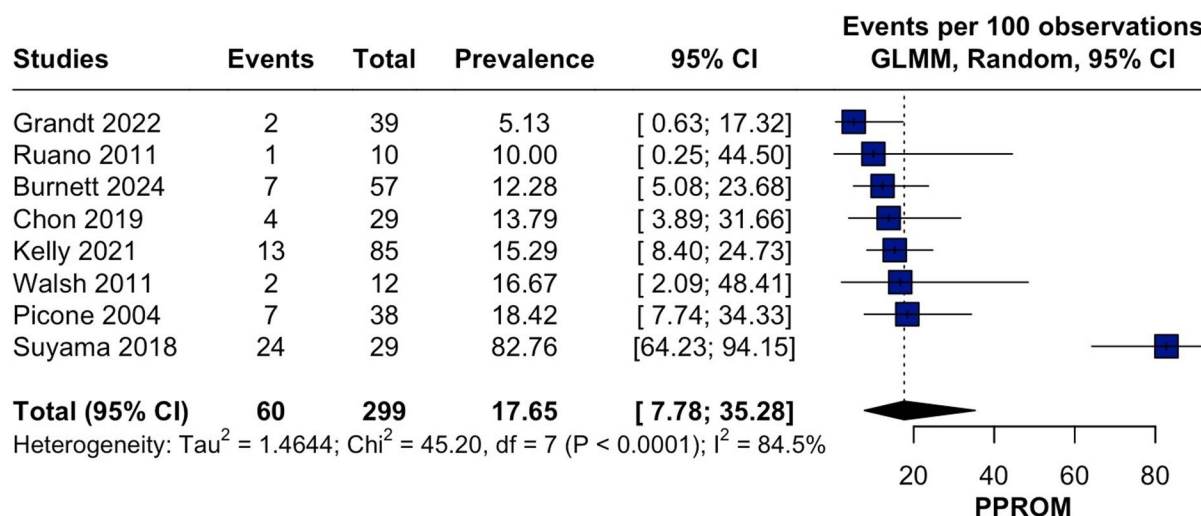


Fig. 6 Forest plot of catheter displacement

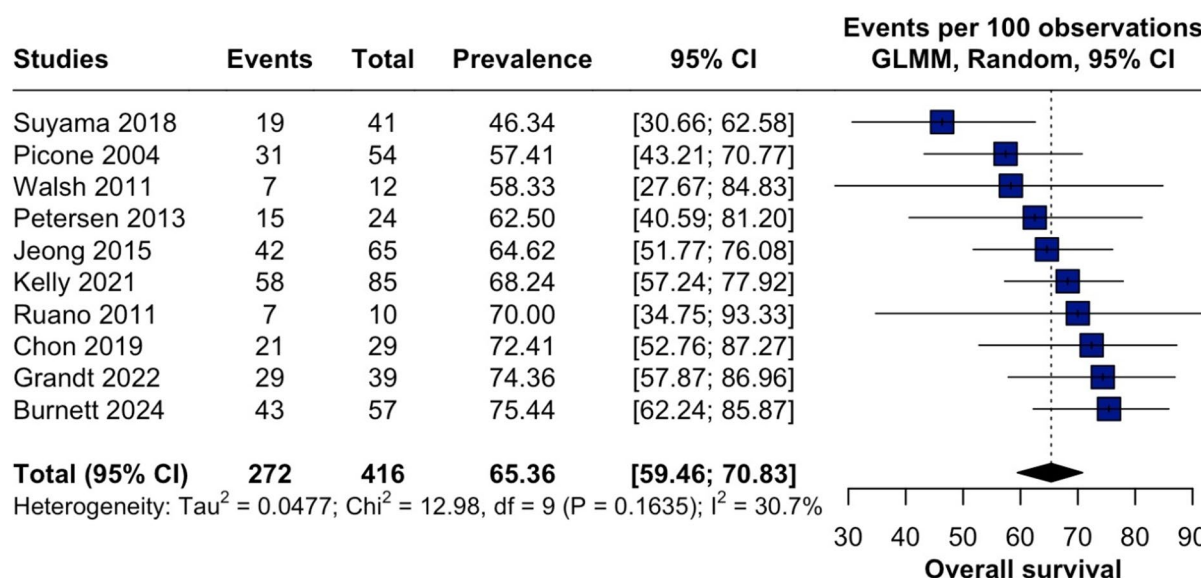


Fig. 7 Forest plot of preterm birth

PPROM was evaluated in eight studies involving a total of 299 fetuses. The combined prevalence was 17.65% (95% CI 7.78–35.28). However, substantial heterogeneity was observed in this outcome ($I^2 = 84.5\%$; $p < 0.001$), reflecting significant variability among the studies. While most studies reported incidences below 20%, one study showed a notably higher frequency of 82.76%, which significantly contributed to the observed inconsistency (Fig. 8).

Chorioamnionitis occurred in three studies involving 134 fetuses, with a total of seven cases reported. The estimated combined prevalence, as calculated using a random-effects model, was 5.22% (95% CI 2.51–10.55), which indicates a low incidence of this complication following the procedure. The individual estimates ranged from 2.56% to 10.53%, and there was low heterogeneity among the studies ($I^2 = 26.1\%$; $p = 0.259$),

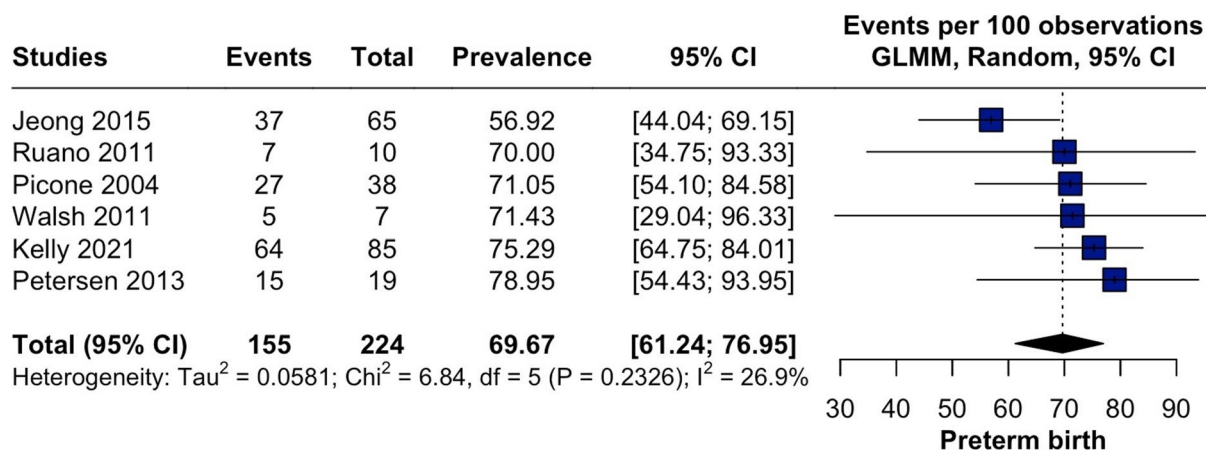


Fig. 8 Forest plot of preterm premature rupture of membranes

which suggests that the results were consistent across the evaluated populations (Fig. 9).

DISCUSSION

This systematic review and meta-analysis consolidated data from ten retrospective cohort studies, encompassing 416 fetuses who underwent pleuro-amniotic shunting for pleural effusion. The central finding of this investigation

demonstrates the potential benefits of this intervention, with a favorable overall survival rate of 65.36% (95% CI 59.46–70.83) and a pooled fetal hydrops resolution rate of 62.25%. However, our analysis also quantifies the clinical cost of the intervention, highlighting that the survival benefit is accompanied by significant rates of obstetric morbidity, including preterm birth (69.67%), catheter displacement (17.13%), and PPROM (17.65%). These findings underscore that, although the procedure has an excellent life-saving potential, it invariably converts the

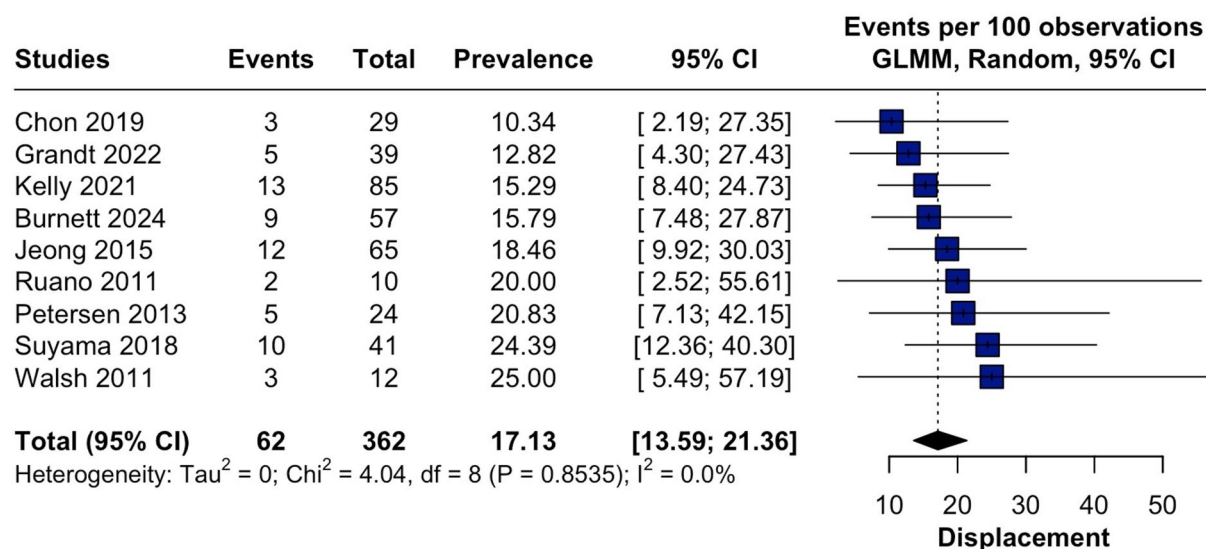


Fig. 9 Forest plot of chorioamnionitis

pregnancy to a high-risk status and demands early intensive intervention.

The presence of fetal hydrops at the time of diagnosis is classically recognized as the most compelling negative predictor in cases of pleural effusion, reflecting a state of impending heart failure due to continuous compression. The data extracted from our cohort confirm this prognostic dichotomy. The analysis by Jeong et al. [23] revealed a substantial difference in survival between the non-hydrotic group (93.3%) and the hydrotic group (56.0%) undergoing shunting. In this context, the insertion of the drain acts directly to relieve intrathoracic pressure, allowing for the decompression of the cardiac chambers and the subsequent restoration of fetal cardiac output.

The most critical prognostic turning point, therefore, is the ultrasonographic confirmation of hydrops reversal following the shunt. Our meta-analysis indicates a complete absence of heterogeneity ($I^2=0\%$) in the outcome of hydrops resolution, demonstrating a highly consistent physiological response to mechanical decompression across different global research centers. When this in utero reversal is achieved, the baseline prognosis undergoes a drastic change. The study by Kelly et al. [9], included in this review, perfectly illustrates this phenomenon by demonstrating that hydrotic fetuses who reversed the condition after drainage achieved a survival rate of 67.3%, approaching the outcomes observed in fetuses who never developed hydrops and surpassing the initial prognosis.

Given the considerable clinical costs and obstetric morbidities previously highlighted, fetal therapy must not be viewed as an isolated surgical intervention. Instead, the inherent risks of the procedure demand a complex, highly coordinated multidisciplinary clinical management strategy. The survival of these neonates relies heavily on the anesthesiology team for meticulous planning of high-risk deliveries, as well as the immediate availability of advanced neonatal intensive care.

The statistical consistency observed across specific outcomes supports the findings of this meta-analysis. The analyses for fetal hydrops resolution and catheter displacement demonstrated

no statistical heterogeneity ($I^2=0\%$). This agreement across different centers suggests a uniform physiological response to mechanical decompression and a stable rate of device-related complications across institutional settings. Conversely, the outcome of PPRM exhibited high heterogeneity ($I^2=84.5\%$). This variability is primarily attributable to a single cohort reporting an incidence of 82.76%, which affected the pooled estimate and suggests that specific institutional protocols, intervention timing, or patient selection criteria may influence membrane integrity following the procedure.

When interpreting these results, one must acknowledge the methodological constraints inherent to the available literature. According to the ROBINS-I tool, all included studies were assessed as having an overall moderate risk of bias. This classification was determined by the “confounding factors” domain, a limitation associated with the retrospective and observational design of the primary cohorts. As a result of the rarity of isolated fetal pleural effusion, executing large-scale randomized controlled trials presents practical and ethical challenges. The remaining evaluated domains—including participant selection, deviations from intended interventions, and outcome measurement—were scored as having a low risk of bias. Despite the lack of randomization, the available evidence provides a basis for informing clinical practice.

The overall survival rate of 65.36% observed with pleuro-amniotic shunting provides a context for evaluating its role among alternative management strategies. Expectant management and therapeutic thoracentesis are often considered for primary fetal pleural effusion. Although thoracentesis is a simpler procedure, it is frequently limited by rapid fluid reaccumulation, which necessitates repeated interventions and consequently increases the cumulative risk of intra-amniotic infection and PPRM [28]. Current reviews, such as the analysis by Abiad et al. [29], indicate that while conservative management may be appropriate for mild or stable effusions, pleuro-amniotic shunting provides sustained intrathoracic decompression, making it a more definitive intervention for progressive or severe cases to avoid the morbidity associated with multiple needle insertions.

The primary limitation of this systematic review and meta-analysis is the reliance on retrospective cohort studies, as no randomized controlled trials were available for inclusion. This methodological constraint is expected because of the rarity of isolated fetal pleural effusion, which complicates the design and execution of large-scale, prospective clinical trials. Consequently, the analyzed cohorts possess relatively small sample sizes, and the inherent risk of unmeasured confounding factors restricts the ability to establish definitive causal relationships between the intervention and the outcomes. Furthermore, the high heterogeneity observed in specific complications, such as PPRM, indicates that variations in institutional protocols, patient selection, and operator experience may influence the reported results.

CONCLUSION

Pleuro-amniotic shunting represents a viable therapeutic strategy for isolated fetal pleural effusion, yielding an overall survival rate of 65.36% and frequently facilitating the resolution of fetal hydrops. However, this procedure should not be approached as an isolated surgical intervention because of the high frequency of associated obstetric morbidities, particularly preterm birth. Optimizing perinatal outcomes necessitates a comprehensive multidisciplinary clinical management strategy. The coordinated involvement of specialized nursing, psychology, and anesthesiology teams is required to manage complex neonatal intensive care, address parental psychological distress, and safely execute high-risk deliveries. Future multicenter prospective studies are needed to refine these multidisciplinary protocols and further clarify long-term neonatal trajectories.

Authors Contribution. Enzo Lofredo Amorim: Conceptualization, methodology, literature search, data curation, formal analysis, investigation, writing—original draft, and writing—review and editing. Edward Araujo Júnior: Conceptualization, methodology, supervision, validation, interpretation of results, and

writing—review and editing. Mucio Cevulla da Silva Lourenço: Literature search, data curation, investigation, and writing—review and editing. Daniel Giatti de Sousa: Literature search, data curation, investigation, and writing—review and editing. Felipe Muniz Ferreira: Literature search, data curation, investigation, and writing—review and editing. Maria Fernanda dos Santos Lobo: Literature search, data curation, investigation, and writing—review and editing. Henrique Provinciatto: Methodology, formal analysis, statistical analysis, interpretation of results, and writing—review and editing. Eduardo Moreira Nader: Methodology, investigation, interpretation of results, and writing—review and editing. Antonio Braga: Conceptualization, methodology, supervision, interpretation of results, and writing—review and editing. Roberta Granese: Conceptualization, methodology, supervision, interpretation of results, and writing—review and editing. All authors contributed to the conception and design of the study, critically revised the manuscript for important intellectual content, approved the final version, and agreed to be accountable for all aspects of the work.

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Data Availability. The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of Interest. Roberta Granese is an Editorial Board member of *Advances in Therapy*. Roberta Granese was not involved in the selection of peer reviewers for the manuscript nor any of the subsequent editorial decisions. Enzo Lofredo Amorim, Edward Araujo Júnior, Mucio Cevulla da Silva Lourenço, Daniel Giatti de Sousa, Felipe Muniz Ferreira, Maria Fernanda dos Santos Lobo, Henrique Provinciatto, Eduardo Moreira Nader, and Antonio Braga declare no conflict of interest regarding this manuscript.

Ethical Approval. This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

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REFERENCES

- Buttiker V, Fanconi S, Burger R. Chylothorax in children. Guidelines for diagnosis and management. *Chest*. 1999;116:682–7.
- Achiron R, Weissman A, Lipitz S, Mashiach S, Goldman B. Fetal pleural effusion: the risk of fetal trisomy. *Gynecol Obstet Investig*. 1995;39:153–6.
- Yang X, Yang D, Deng Q, et al. Risk factors associated with fetal pleural effusion in prenatal diagnosis: a retrospective study in a single institute in Southern China. *J Obstet Gynaecol*. 2020;40(4):443–7.
- Waller K, Chaithongwongwatthana S, Yamasmit W, Donnenfeld AE. Chromosomal abnormalities among 246 fetuses with pleural effusions detected on prenatal ultrasound examination: factors associated with an increased risk of aneuploidy. *Genet Med*. 2005;7(6):417–21.
- Rustico MA, Lanna M, Coviello D, Smoleniec J, Nicolini U. Fetal pleural effusion. *Prenat Diagn*. 2007;27(9):793–9.
- Aubard Y, Derouineau I, Aubard V, Chalifour V, Preux P-M. Primary fetal hydrothorax: a literature review and proposed antenatal clinical strategy. *Fetal Diagn Ther*. 1998;13(6):325e33.
- Weber AM, Philipson EH. Fetal pleural effusion: a review and meta-analysis for prognostic indicators. *Obstet Gynecol*. 1992;79(2):281e6.
- Witlox RS, Lopriore E, Rijken M, Klumper FJ, Oepkes D, van Klink JM. Long-term neurodevelopmental and respiratory outcome after intrauterine therapy for fetal thoracic abnormalities. *Fetal Diagn Ther*. 2018;45:162–7.
- Kelly EN, Seaward G, Ye XY, et al. Short- and long-term outcome of fetuses undergoing thoracoamniotic shunting for fetal hydrothorax. *Ultrasound Obstet Gynecol*. 2021;57(4):624–30.
- Picone O, Benachi A, Mandelbrot L, Ruano R, Dumez Y, Dommergues M. Emergency thoracoamniotic shunting in cases with compressive pleural effusion with hydrops: A retrospective study of 60 cases. *J Gynecol Obstet Biol Reprod (Paris)*. 2006;35(7):652–7.
- Abbasi N, Windrim R, Keunen J, et al. Perinatal outcome in fetuses with dislodged thoraco-amniotic shunts. *Fetal Diagn Ther*. 2021;48(6):430–9.
- Yinon Y, Grisaru-Granovsky S, Chaddha V, et al. Perinatal outcome following fetal chest shunt insertion for pleural effusion. *Ultrasound Obstet Gynecol*. 2010;36(1):58–64.
- Picone O, Benachi A, Mandelbrot L, Ruano R, Dumez Y, Dommergues M. Thoracoamniotic shunting for fetal pleural effusions with hydrops. *Am J Obstet Gynecol*. 2004;191(6):2047–50.
- Sepulveda W, Galindo A, Sosa A, Diaz L, Flores X, De la Fuente P. Intrathoracic dislodgement of pleuro-amniotic shunt. *Fetal Diagn Ther*. 2005;20(2):102e5.
- Brown R, Nicolaides K. Constriction band of the arm following insertion of a pleuro-amniotic shunt. *Ultrasound Obstet Gynecol*. 2000;15(5):439–40.
- Merchant AM, Peranteau W, Wilson RD, et al. Postnatal chest wall deformities after fetal thoracoamniotic shunting for congenital cystic adenomatoid malformation. *Fetal Diagn Ther*. 2007;22(6):435–9.
- Lanna M, Consonni D, Faiola S, et al. Fetal hydrothorax treated with pleuro-amniotic shunting: fetal and maternal complications and long-term outcomes. *Fetal Diagn Ther*. 2023;50(2):115–20.

18. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan-a web and mobile app for systematic reviews. *Syst Rev*. 2016;5(1):210.
19. Sterne JA, Hernán MA, Reeves BC, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. *BMJ*. 2016;355:i4919.
20. Suyama F, Ozawa K, Ogawa K, Sugibayashi R, Wada S, Sago H. Fetal lung size after thoracoamniotic shunting reflects survival in primary fetal hydrothorax with hydrops. *J Obstet Gynaecol Res*. 2018;44(7):1216–20.
21. Grandt J, Gottschalk I, Geipel A, et al. Intrauterine thoracoamniotic shunting of fetal hydrothorax with the Somatex intrauterine shunt: intrauterine course and postnatal outcome. *J Clin Med*. 2022;11(9):2312.
22. Chon AH, Chmait HR, Korst LM, Llanes A, Ouzounian JG, Chmait RH. Long-term outcomes after thoracoamniotic shunt for pleural effusions with secondary hydrops. *J Surg Res*. 2019;233:304–9.
23. Jeong BD, Won HS, Lee MY, Shim JY, Lee PR, Kim A. Perinatal outcomes of fetal pleural effusion following thoracoamniotic shunting. *Prenat Diagn*. 2015;35(13):1365–70.
24. Walsh CA, Vallerie AM, Baxi LV. Prenatal diagnosis and natural history of fetuses presenting with pleural effusion. *Prenat Diagn*. 2011;31(3):296–9.
25. Burnett W, Moldenhauer JS, Khalek N, et al. Risk of genetic abnormality in fetuses with unilateral versus bilateral pleural effusions. *Prenat Diagn*. 2024. <https://doi.org/10.1002/pd.6657>.
26. Petersen SG, Gibbons KS, Johns J, Gardener GJ. The outcome of isolated primary fetal hydrothorax: a 10-year review from a tertiary center. *Fetal Diagn Ther*. 2013;34(2):69–76.
27. Walsh J, Mahony R, Higgins S, McParland P, Carroll S, McAuliffe F. Thoraco-amniotic shunting for fetal pleural effusion: a case series. *Ir Med J*. 2011;104(7):205–8.
28. Abbasi N, Ryan G. Fetal primary pleural effusions: prenatal diagnosis and management. *Best Pract Res Clin Obstet Gynaecol*. 2019;58:66–77.
29. Abiad M, Javinani A, Lopez MC, et al. Diagnosis and management of primary fetal pleural effusion: a narrative review. *Best Pract Res Clin Obstet Gynaecol*. 2026;105:102707.

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