

Hybrid Stage I Versus Norwood Procedure in Hypoplastic Left Heart Syndrome: A Comparative Review of Survival, Morbidity, and Neurodevelopmental Outcomes

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Introduction: Hypoplastic left heart syndrome (HLHS) is a critical congenital heart disease with high neonatal mortality if untreated. The Norwood procedure has been the standard Stage I palliation for decades, achieving hospital survival rates exceeding 90% in experienced centers. The Hybrid Stage I approach combining bilateral pulmonary artery banding, ductal stenting, and atrial septostomy has emerged as an alternative, particularly for high-risk neonates such as those with prematurity, low birth weight, or comorbidities. Despite increasing adoption, comparative evidence regarding survival, morbidity, and neurodevelopmental outcomes remains debated.

Methods: A narrative synthesis was conducted using systematic reviews, meta-analyses, and expert reviews published between 2016 and 2024. Key sources included meta-analyses comparing Hybrid and Norwood procedures (Cao et al., 2018; Iskander et al., 2024), a focused review on neurodevelopmental outcomes (Knirsch et al., 2023), and comprehensive reviews of therapeutic strategies (Ohye et al., 2016; Zea-Vera et al., 2024). Outcomes of interest were early and mid-term survival, morbidity and reintervention rates, and neurodevelopmental trajectories

Results: Meta-analysis of 14 studies (Cao et al., 2018) demonstrated significantly higher early mortality in Hybrid patients (RR 1.54, 95% CI 1.02–2.34) and inferior six-month and one-year transplant-free survival compared to Norwood. Hybrid patients also required more reinterventions (RR 1.48, 95% CI 1.09–2.01). A more recent meta-analysis (Iskander et al., 2024) suggested narrowing differences in survival, though Hybrid remained associated with higher morbidity and reintervention burden. Neurodevelopmental outcomes were impaired in both groups, with only minor differences attributable to the type of Stage I palliation (Knirsch et al., 2023). Instead, prematurity, low birth weight, and perioperative instability were stronger predictors of adverse neurodevelopment. Expert reviews emphasized that while Norwood remains the gold standard for standard-risk neonates, the Hybrid approach provides a valuable bridge strategy for high-risk infants, albeit at the cost of a more complex comprehensive Stage II. Emerging transcatheter-only Stage I strategies may further reduce surgical morbidity, though long-term data are limited (Zea-Vera et al., 2024).

Conclusion: The Norwood procedure continues to offer superior long-term survival for standard-risk HLHS neonates, while the Hybrid Stage I approach serves as an important alternative for high-risk patients. Although Hybrid palliation avoids neonatal cardiopulmonary bypass, it is associated with increased reinterventions and comparable neurodevelopmental outcomes. Patient selection remains critical, with outcomes influenced more by baseline risk factors than by the choice of Stage I palliation. Future multicenter prospective studies are needed to clarify long-term neurodevelopmental trajectories and to evaluate the role of emerging transcatheter strategies.

