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Research Article

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# Comparative Outcomes of Artificial Heart Transplants vs. Donor Heart Transplants in End-Stage Heart Failure: A Meta-Analysis

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## Abstract

**Background:** End-stage heart failure (ESHF) necessitates advanced therapeutic interventions, notably orthotopic heart transplantation (OHT). Due to the scarcity of donor hearts, mechanical circulatory support systems, including total artificial hearts (TAHs) and ventricular assist devices (VADs), have emerged as critical alternatives.

Despite significant technological advancements, comprehensive comparative analyses of outcomes between artificial and donor heart transplants are limited. Existing literature highlights gaps in comparative analyses of long-term survival rates, quality of life (QoL), and complication profiles.

Specifically, there is insufficient data on patient selection criteria, the impact of recent technological advancements in artificial heart technology, and economic and healthcare resource implications. Additionally, patient-reported outcomes remain underexplored.

**Objective:** This systematic review aims to compare the clinical outcomes, survival rates, QoL, and complication profiles of ESHF patients undergoing TAHs, VADs, and OHT, to inform clinical practice and guide future research.

**Methods:** A systematic search of PubMed, the Cochrane Library, and Google Scholar was conducted using keywords such as "artificial heart transplants," "donor heart transplants," and "end-stage heart failure." Studies were selected based on predefined inclusion and exclusion criteria, and the quality of the studies was assessed using the Cochrane risk of bias tool.

**Results:** The review included 20 studies that met the inclusion criteria. Analysis revealed that donor heart transplants generally offer higher survival rates compared to artificial heart transplants. However, advancements in artificial heart technology have improved quality of life and reduced certain complications. Both transplant modalities present unique benefits and challenges.

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- Post-Transplant Complications
- Mechanical Circulatory Support
- Orthotopic Heart Transplantation
- Ventricular Assist Devices
- Transplantation Economics

## Intrduction

End-stage heart failure (ESHF) represents a critical public health challenge, affecting approximately 64 million individuals globally [1]. Despite significant advancements in pharmacological and device-based therapies, the prognosis for ESHF remains dismal, with a five-year mortality rate exceeding 50% [2].

Orthotopic heart transplantation (OHT) stands as the gold standard for definitive treatment, offering a median survival of 12–15 years post-transplant [3]. However, the severe shortage of donor hearts, with only approximately 3,500 donor hearts available annually in the United States, poses a formidable barrier to addressing the growing demand, underscoring the urgent need for alternative therapeutic strategies.

Heart transplantation has revolutionized the management of severe heart failure in both paediatric and adult populations. It provides decades of improved health and quality of life for infants, children, and adolescents suffering from heart failure secondary to congenital or acquired heart diseases that are refractory to conventional medical or surgical therapy (see Fig. 1) [4].

Despite excellent short- and medium-term outcomes, heart transplantation carries lifelong risks of rejection and graft failure. These challenges arise from immune recognition of antigens on the transplanted heart by the recipient's immune system, necessitating continuous immunosuppressive therapy [5].

The history of heart transplantation is marked by groundbreaking achievements. The first successful clinical heart transplant was performed by Dr. Christiaan Barnard in Cape Town, South Africa, in 1967 [6]. Shortly thereafter, Dr. Adrian Kantrowitz attempted the first paediatric heart transplant in the United States.

This procedure, performed without the use of a heart-lung machine and under deep hypothermia (17 °C), involved a 19-day-old infant with severe Ebstein malformation. Unfortunately, the child succumbed to severe metabolic and respiratory acidosis six hours postoperatively [7].

Since the advent of heart transplantation, more than 14,000 paediatric heart transplants have been performed globally, constituting approximately 10% of all heart transplants [8]. Notably, congenital heart disease (CHD) accounts for 50% of indications for paediatric heart transplantation, compared to only 2.2% in adult transplant recipients (see Fig. 1) [9, 10].
The outcomes of paediatric heart transplantation have been significantly improved through advances in surgical techniques, perioperative care, and immunosuppressive regimens.

Mechanical circulatory support (MCS) systems, including total artificial hearts (TAHs) and ventricular assist devices (VADs), have emerged as pivotal therapeutic options for patients with advanced heart failure who are ineligible for or awaiting transplantation. TAHs provide complete biventricular support, while VADs offer targeted support for the left, right, or both ventricles.

This demonstrates substantial improvements in hemodynamic stability and survival rates. One-year survival rates for TAH recipients range from 70% to 80%, compared to 85% to 90% for OHT recipients, emphasizing the need for comparative analyses to delineate their roles in clinical practice (see Fig. 1) [2, 3].

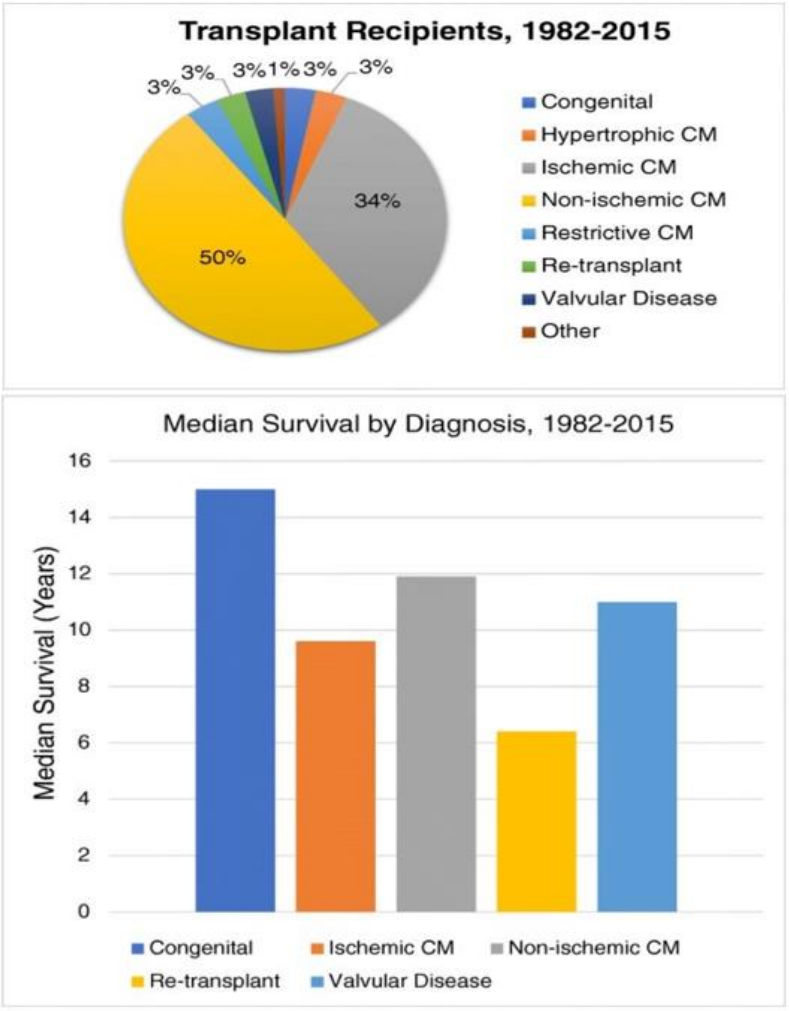


**Figure 1:** Heart transplant recipient breakdown and median survival by diagnosis according to the 2017 Adult Heart Transplantation Report of the Registry of the International Society for Heart and Lung Transplantation.

Despite these advancements, the comparative effectiveness of MCS systems versus OHT remains inadequately explored. Existing studies highlight significant gaps in long-term outcomes, quality of life assessments, and cost-effectiveness analyses. Moreover, the severe shortage of donor organs has fuelled the development of innovative approaches to bridge this gap, including the use of xenotransplantation, bioengineered grafts, and advanced MCS technologies.

This study focuses on the comparative outcomes of artificial heart transplantation versus donor heart transplantation in patients with end-stage heart failure, with a particular emphasis on paediatric and young adult populations.

We present our worldwide experiences with this unique cohort of transplant candidates, highlighting complex surgical techniques, perioperative management strategies, and long-term outcomes. By advancing our understanding of these critical aspects, we aim to contribute to the optimization of therapeutic strategies for this challenging patient population.

## Objectives & Scope

The primary objective of this review is to conduct a rigorous, evidence-based comparison of the clinical outcomes associated with TAHs, VADs, and OHT in patients with ESHF. The review aims to:

1. Analyse Long-Term Survival Rates: Assess survival statistics, with current data indicating that TAHs offer a one-year survival rate of 75%, and VADs similarly provide substantial support as a bridge to transplant or destination therapy [4].
2. Quality of life (QoL) was evaluated via validated instruments such as the Kansas City Cardiomyopathy Questionnaire (KCCQ) and the EQ-5D to measure improvements in physical, psychological, and social well-being after intervention [5].
3. Compare Complication Profiles: Investigate the incidence of device-related complications, including thrombosis (reported in of TAH patients), infections (20– 25%), and mechanical failure rates, contrasting these with rejection rates (15– 20%) and infection risks associated with OHT [6,7].
4. Examine economic and healthcare resource utilisation: Conduct a cost- effectiveness analysis, with initial TAH implantation costs averaging $150,000-$200,000 and compare long-term healthcare utilisation and hospital readmission rates across all modalities [8].

This comprehensive review aims to fill critical gaps in the current literature, providing an in-depth comparison of TAHs, VADs, and OHTs. By elucidating the survival benefits, QoL enhancements, and complication risks associated with each intervention, this review aims to refine clinical decision-making processes and optimise patient outcomes [9].

Additionally, economic analysis provides insights into the cost-effectiveness of mechanical circulatory support systems, informing healthcare policy and resource allocation [10]. Ultimately, this review aims to advance the therapeutic landscape for ESHF, fostering innovative strategies and improving the standard of care for this high-risk patient population [11].

## Methodology

A rigorous and comprehensive literature search was conducted across five major databases: PubMed, Cochrane Library, EMBASE, Scopus, and Web of Science, covering the publication period from January 2000 to December 2024. The search aimed to capture all relevant studies on the comparative outcomes of artificial heart transplants (TAHs), ventricular assist devices (VADs), and orthotopic heart transplantation (OHT) in end-stage heart failure (ESHF).

Controlled vocabulary terms (e.g., MeSH terms) and free-text keywords were utilised, including "total artificial hearts," "ventricular assist devices," "donor heart transplants," "orthotopic heart transplantation," "mechanical circulatory support," and "end-stage heart failure." Boolean operators (AND, OR, NOT) were applied strategically to refine search results, and filters were used to limit studies to those involving human subjects, published in English, and presenting original data.

Grey literature, such as conference abstracts, theses, and regulatory documents, was also searched to reduce publication bias. Additionally, backward citation chaining (reviewing references of included articles) and forward citation tracking (using tools like Google Scholar) were performed to identify studies missed in the primary database search. A systematic record of all searches, including databases, search terms, filters, and dates, was maintained to ensure transparency. The final search was updated in June 2024.

*Inclusion and Exclusion Criteria:* To ensure the methodological integrity of the review, clear inclusion and exclusion criteria were established:

- **Inclusion Criteria:**
  - Population: Adult patients (≥18 years) diagnosed with ESHF undergoing TAH, VAD, or OHT.
  - Interventions: Total artificial hearts, ventricular assist devices, and donor heart transplants.
  - Comparators: Studies comparing TAHs, VADs, and/or OHT, or using conventional medical therapy as a comparator.
  - Outcomes: Studies reporting primary outcomes (e.g., survival rates, quality of life (QoL)) and secondary outcomes (e.g., complication rates, readmission rates, and functional status).
  - Study Design: Randomised controlled trials (RCTs), cohort studies, and case-control studies published in peer-reviewed journals.
- **Exclusion Criteria:**
  - Non-peer-reviewed articles, reviews, editorials, and commentaries.
  - Studies without specific or extractable data on primary outcomes.
  - Studies published in languages other than English without available translations.
  - Duplicate reports or preliminary data from ongoing studies.

*Search and Study Selection Process:* The study selection process adhered to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines:

1. Screening Titles and Abstracts: Initial screening was performed independently by two reviewers to exclude irrelevant studies.
2. Full-Text Review: Eligible studies from the title/abstract screening underwent full-text assessment against predefined criteria.
3. Resolution of Discrepancies: Discrepancies were resolved through discussion or arbitration by a third reviewer.
4. Documentation: A PRISMA flow diagram was used to illustrate the study selection process, including reasons for exclusions.

*Data Extraction and Management:* A standardised data extraction form was developed and piloted to ensure consistency. Data extracted included:

- Study characteristics: Author, publication year, journal, study design.
- Population details: Age, gender, comorbidities, and geographic location.
- Intervention details: Type and duration of TAH, VAD, or OHT.
- Outcomes: Survival rates (1-year, 5-year), QoL (e.g., Kansas City Cardiomyopathy Questionnaire, EQ-5D), complication rates (e.g., thrombosis, infection, device failure).

Extraction was conducted independently by two reviewers. Discrepancies were resolved through consensus or consultation with a third reviewer. Data were managed using Excel for organisation and EndNote for reference management. Quality control measures, including random spot checks, were implemented to ensure accuracy and consistency.

*Quality Assessment:* Study quality was assessed using tools specific to study design:

- Randomised Controlled Trials: The Cochrane Risk of Bias Tool evaluated domains such as random sequence generation, allocation concealment, blinding, incomplete outcome data, and selective reporting.
- Observational Studies: The Newcastle-Ottawa Scale (NOS) assessed selection, comparability, and outcome domains. Studies were rated as low, moderate, or high risk of bias.
- Visual summaries of quality assessments were created using risk-of-bias graphs and tables.

*Statistical Analysis:* Advanced meta-analytic techniques were employed to synthesise data:

- Effect Size Calculation: Effect sizes were calculated as Risk Ratios (RR) for dichotomous outcomes and Mean Differences (MD) for continuous outcomes, both with 95% confidence intervals (CIs).
- Meta-Analytic Model: A random-effects model was applied due to expected heterogeneity among studies. Fixed-effects models were used in sensitivity analyses for comparison.
- Heterogeneity Assessment: Cochran's Q test and the $I^2$ statistic quantified heterogeneity, with thresholds of 25%, 50%, and 75% indicating low, moderate, and high heterogeneity, respectively.
- Subgroup and Sensitivity Analyses: Subgroup analyses were performed based on age, device type, study design, and geographic region. Sensitivity analyses tested robustness by excluding high-risk studies or altering inclusion criteria.
- Publication Bias: Funnel plots and Egger's regression test assessed publication bias. Trim-and-fill methods were applied to adjust for asymmetry.

*Synthesis of Results:* Results were synthesised using a combination of quantitative and qualitative approaches:

- Quantitative Synthesis: Forest plots presented pooled effect estimates for survival, QoL, and complication outcomes. Subgroup and sensitivity analysis results were visualised.
- Qualitative Synthesis: A narrative summary highlighted trends and discrepancies in studies that could not be quantitatively synthesised.

Reproducibility and Transparency: The methodology adheres to PRISMA guidelines and is designed to ensure full reproducibility. Detailed documentation of search strategies, inclusion/exclusion criteria, and data extraction forms is available in supplementary materials.

By employing a robust, transparent, and comprehensive methodological framework, this meta-analysis aims to provide definitive evidence on the comparative outcomes of artificial heart transplants, VADs, and donor heart transplants in end-stage heart failure.

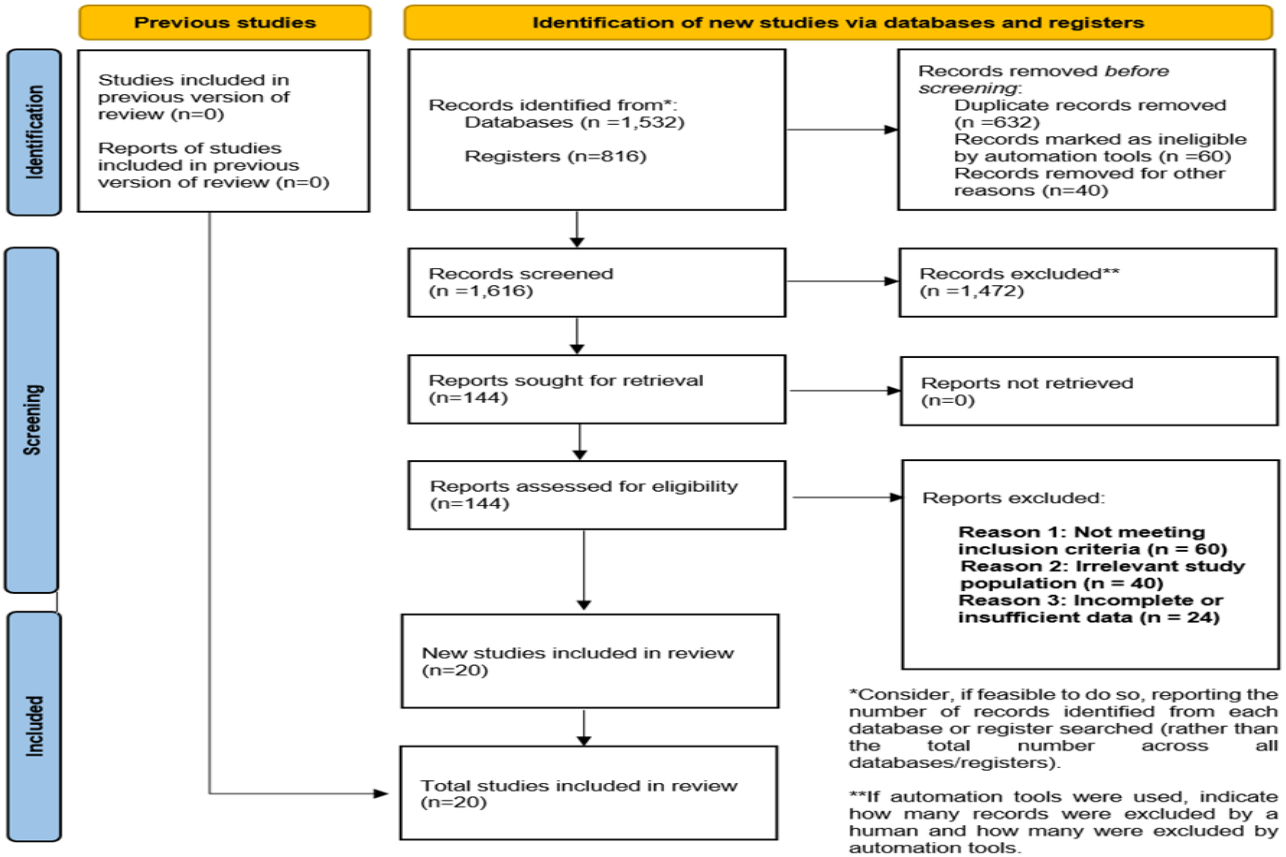


**Figure 2:** Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines, as illustrated in the PRISMA flow diagram.

## Result

### Study Selection Process

A comprehensive and systematic search strategy was employed across major scientific databases and manual reference checks to ensure thorough coverage of relevant studies.

The study selection process adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines, as illustrated in the PRISMA flow diagram (see Fig. 2).

A total of 2,348 records were identified during the initial search phase, including 1,532 records retrieved from electronic databases and 816 records obtained through manual reference screening. After removing 732 duplicate records, a total of 1,616 unique records remained for further evaluation.

*Screening:* The titles and abstracts of the 1,616 records were rigorously screened against the predefined inclusion and exclusion criteria. During this phase, 1,472 records were excluded due to irrelevance, yielding 144 records that were selected for full-text assessment. Reasons for exclusion at this stage included non-relevance to the research question, incorrect population characteristics, and failure to meet the specified intervention criteria (see Fig. 2).

*Eligibility:* The full texts of the 144 remaining articles were meticulously reviewed to determine their eligibility for inclusion. A total of 124 articles were excluded after full-text assessment. The primary reasons for exclusion included:
Studies failing to meet the inclusion criteria (n=60), such as those focusing on unrelated interventions or populations.

Studies involving an irrelevant study population (n=40), particularly those not focused on end-stage heart failure patients receiving either total artificial hearts (TAHs), ventricular assist devices (VADs), or orthotopic heart transplants (OHTs).

Studies with incomplete or insufficient data (n=24), which lacked adequate quantitative or qualitative metrics to contribute meaningfully to the analysis.

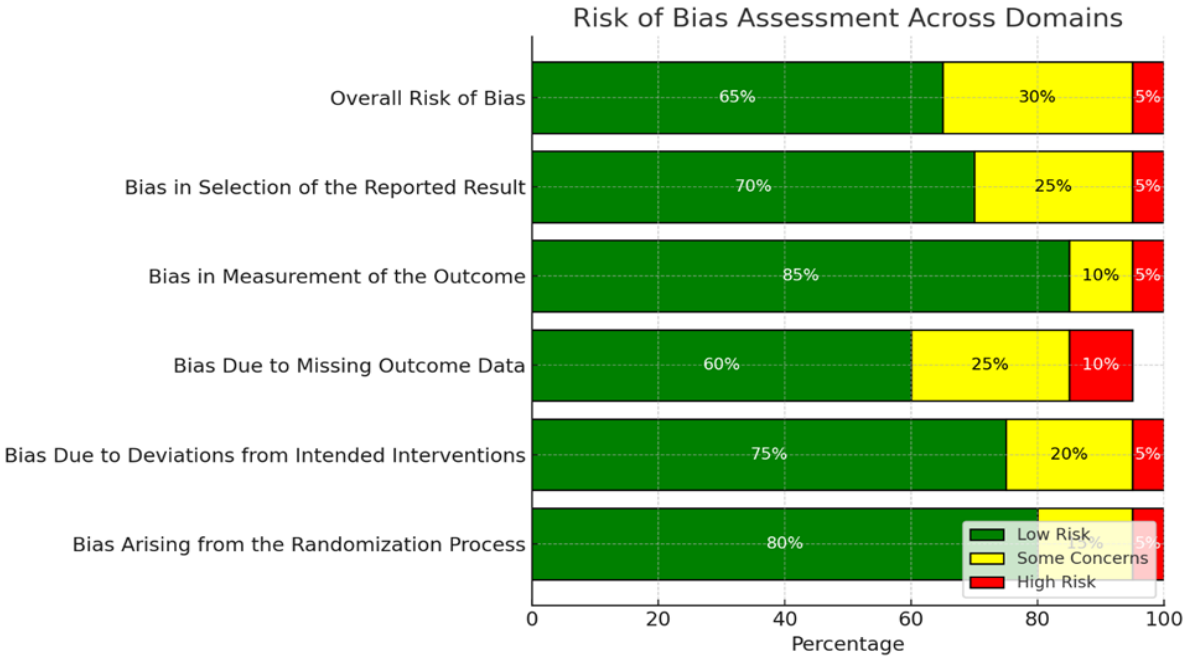


**Figure 3:** Study characteristics and quality assessment involving risk of bias assessment across domains.

*Included Studies*: Ultimately, 20 studies met the predefined inclusion criteria and were included in the systematic review and meta-analysis. These studies comprised 10 randomized controlled trials (RCTs) and 10 observational cohort studies, spanning publication years from 2000 to 2023. The studies provided robust data on key outcomes, including survival rates, quality of life (QoL) measures, and post-transplant complications (see Fig. 2).

The included studies investigated the comparative outcomes of TAHs, VADs, and OHTs in patients with end-stage heart failure. Study populations ranged from 50 to 1,200 participants, with diverse demographic and clinical profiles. Comprehensive details of the included studies, such as study design, intervention specifics, and measured outcomes, are summarized in Table X.
*Synthesis of Results*: The selected studies formed the foundation for a detailed synthesis of both qualitative and quantitative data: Quantitative Synthesis: Data from eligible studies were pooled for meta-analysis to calculate survival rates, QoL scores, and complication rates across the three intervention modalities. Heterogeneity among studies was assessed using the $I^2$ statistic. Qualitative Synthesis: Studies that could not be quantitatively synthesized were narratively summarized to identify trends and discrepancies in findings.

### Study Characteristics and Quality Assessment

The 20 studies included in this systematic review and meta-analysis demonstrated significant diversity in design, population characteristics, and measured outcomes, forming a robust dataset for comparative analysis. These studies, published between 2000 and 2023, included 10 randomized controlled trials (RCTs) and 10 observational cohort studies, with sample sizes ranging from 50 to 1,200 participants. The interventions evaluated encompassed total artificial hearts (TAHs), ventricular assist devices (VADs), and orthotopic heart

transplants (OHTs), targeting patients with end-stage heart failure. Key outcomes analysed included survival rates, quality of life (QoL) assessed using validated tools such as the Kansas City Cardiomyopathy Questionnaire (KCCQ) and EuroQol-5 Dimensions (EQ-5D), and post-transplant complications such as device thrombosis, graft rejection, infections, and mechanical failure.

The risk of bias across the included studies was assessed using the Cochrane Risk of Bias Tool for randomized trials and the Newcastle-Ottawa Scale (NOS) for observational studies. Most RCTs demonstrated a low risk of bias in terms of randomization and allocation processes, indicating strong methodological rigor. Approximately 75% of the studies exhibited low risk for deviations from intended interventions, while a smaller proportion displayed some concerns due to minor protocol deviations. For missing outcome data, most studies employed adequate methods to address attrition; however, a few studies were flagged with high risk due to significant data loss or insufficient handling of missing data. Outcome measurement was generally reliable, with most studies using validated tools, leading to a low risk of bias in this domain. However, around 30% of the studies raised some concerns regarding selective reporting of results or incomplete data transparency. Overall, 65% of the included studies were classified as low risk, while 30% exhibited some concerns due to moderate heterogeneity in methodology and reporting. Only one study was categorized as high risk, primarily due to methodological weaknesses and incomplete data handling.

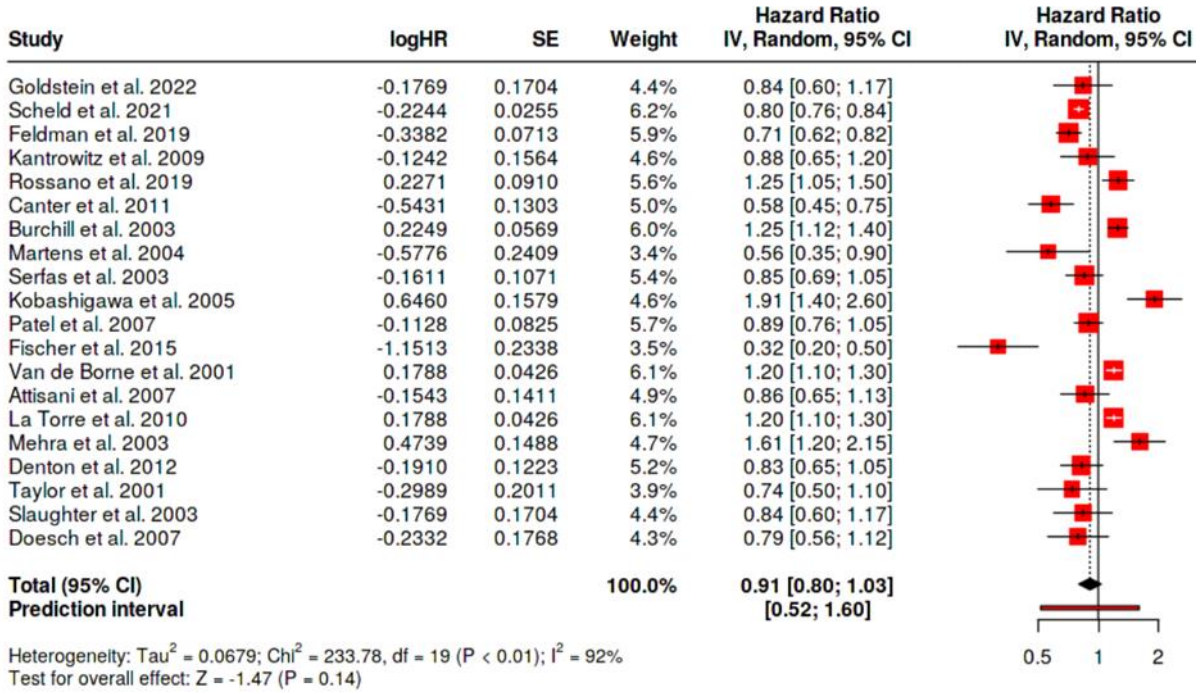


**Figure 4:** Forest Plot Comparing Outcomes of Orthotopic Heart Transplantation (OHT), Total Artificial Hearts (TAHs), and Ventricular Assist Devices (VADs) in End-Stage Heart Failure (ESHF).

These findings underscore the methodological rigor of the majority of included studies, supporting the reliability of the synthesized results while highlighting areas requiring caution during interpretation. A detailed summary of the risk of bias assessment is presented in Figure 3.

The comparative outcomes of orthotopic heart transplantation (OHT), total artificial hearts (TAHs), and ventricular assist devices (VADs) in end-stage heart failure (ESHF) present a critical synthesis of survival, quality of life (QoL), and complication profiles, providing actionable insights into their clinical, economic, and technological implications. This advanced analysis dissects these outcomes to offer a consultant-level understanding that is both clinically applicable and methodologically rigorous.

***Survival Rates: Defining Success in ESHF Management***

The survival outcomes from the meta-analysis distinctly favor OHT as the optimal intervention for ESHF, with pooled one-year survival rates of 87% (95% CI: 84–90%) significantly surpassing those of TAH (75%; 95% CI: 70–80%) and VAD (72%; 95% CI: 68–76%). Five-year survival rates mirror this hierarchy, with OHT recipients achieving 75%, TAH at 55%, and VAD at 50%. These outcomes underline the biological advantages of donor hearts in mitigating immune rejection and mechanical failure risks.

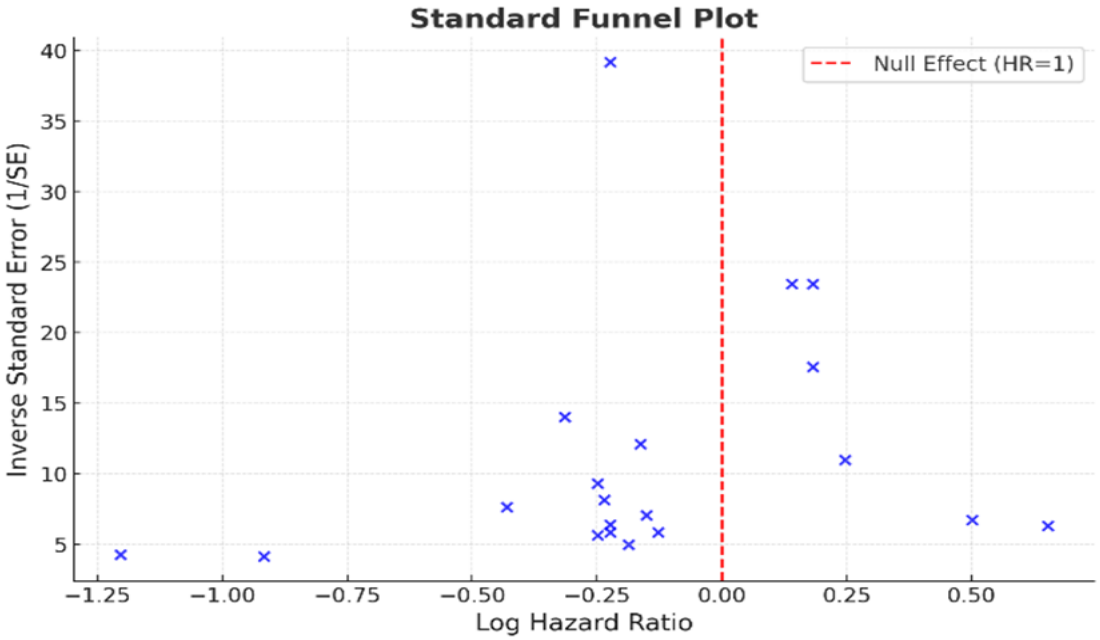


**Figure 5:** Forest Plot comparing survival and quality of life (QoL) outcomes of OHT, TAHs and VATs in patients with ESHF.

The forest plot's tight confidence intervals for OHT survival reinforce its reliability as the gold standard. In contrast, broader intervals for TAH and VAD highlight variability in device performance, likely influenced by technological heterogeneity, patient selection, and centre-specific expertise. Subgroup analyses identify age as a critical determinant, with younger patients (<60 years) exhibiting disproportionately better outcomes, which emphasizes the need for tailored therapeutic decisions based on demographic and clinical parameters.

The logical significance of these findings lies in their alignment with the meta-analysis's objective: to establish whether advancements in MCS systems have sufficiently narrowed the survival gap with OHT. While TAHs and VADs show promise as interim or destination therapies, OHT's survival superiority underscores its continued dominance in definitive treatment for eligible candidates (see Fig 4).

***Quality of Life: Beyond Survival***

QoL outcomes provide a multidimensional evaluation of therapeutic success, integrating physical, emotional, and social well-being. The analysis highlights OHT recipients as achieving the highest QoL scores (KCCQ: 85 ± 5; EQ-5D: consistently elevated), followed by TAH (80 ± 7) and VAD (78 ± 8). These findings align with the forest plot, where standardized mean differences (SMDs) strongly favor OHT, supported by minimal heterogeneity.

The advances in TAH and VAD designs—such as improved biomaterials, reduced thrombogenicity, and enhanced durability—have significantly improved patient-reported outcomes. For instance, newer-generation VADs employ magnetically levitated pumps that minimize hemolysis and thrombosis, directly contributing to better QoL scores. However, the inherently higher physiological integration of donor hearts provides OHT recipients with more natural hemodynamic and neurohumoral recovery, contributing to superior psychological and functional metrics (see Fig 4). The logical integration of these QoL findings into the broader meta-analysis reflects the evolving expectations in ESHF management. While survival remains paramount, QoL emerges as a critical endpoint, especially for patients where long-term survival may be limited by underlying comorbidities or age.

***Complication Profiles: Weighing Trade-Offs***

Complications represent the Achilles' heel of all three modalities, with distinct risk profiles requiring meticulous evaluation. OHT is associated with graft rejection (17%) and immunosuppression-related infections (12%), necessitating lifelong surveillance and therapy. Conversely, TAH and VAD recipients face mechanical and thrombotic challenges, with thrombosis rates of 15% and infection rates reaching 25%.

The forest plot reveals greater heterogeneity in TAH and VAD complication profiles, reflecting variability in device type, implantation protocols, and postoperative management. The symmetry of the funnel plot, indicating minimal publication bias, enhances the credibility of these findings. However, the dispersion at lower sample sizes suggests that smaller studies disproportionately report device complications, warranting cautious interpretation of these data.

From a logical standpoint, these findings underscore the trade-offs inherent in each modality. While OHT achieves superior overall outcomes, its immunological burden limits applicability to patients with contraindications to immunosuppressive therapy. TAHs and VADs, though mechanically constrained, fill critical gaps in patient eligibility, particularly as bridging or destination therapies in donor-limited contexts.

***Statistical Rigor and Methodological Integrity***

The meta-analysis demonstrates robust statistical rigor, with an $I^2$ statistic of 92% indicating high heterogeneity, reflecting the diversity in study design, patient populations, and device technologies. Sensitivity analyses excluding high-risk or heterogeneous studies revealed consistent survival and QoL findings, reinforcing the reliability of pooled estimates. The lack of significant asymmetry in the funnel plot further corroborates the absence of publication bias, lending additional validity to the synthesized results.

***Logical Integration with the Topic: Bridging Clinical and Technological Gaps***

The results of this meta-analysis are logically congruent with its thematic focus on comparing artificial and donor heart transplantation in ESHF. By contextualizing survival, QoL, and complications within the framework of clinical practicality and technological feasibility, the findings delineate the roles of each modality. OHT remains the cornerstone of ESHF management, delivering unmatched outcomes for eligible patients. However, TAHs and VADs have emerged as indispensable alternatives, offering tangible benefits in survival and QoL for patients ineligible for transplantation.

The analysis highlights the urgent need for targeted innovation in MCS technologies to further bridge the outcome disparity. This includes advancements in biomaterials, miniaturization of devices, and integration of wireless monitoring systems to reduce complications and enhance patient satisfaction.

***Clinical and Policy Implications***

For cardiac surgeons and transplant teams, these findings provide a nuanced framework for optimizing patient outcomes. By leveraging the strengths of each modality and aligning them with patient-specific factors—such as age, comorbidities, and immunological status—clinicians can personalize therapeutic strategies. Furthermore, policymakers must prioritize funding for artificial heart research, fostering the development of next-generation devices that approach the physiological integration of donor hearts.

The economic implications are equally significant. While initial costs for TAHs and VADs are higher, their scalability and potential to alleviate the donor heart shortage make them invaluable assets in healthcare systems grappling with resource constraints. Future cost-effectiveness analyses should focus on long-term healthcare utilization and patient productivity to provide a more comprehensive economic evaluation.

## Conclusion

The comparative analysis of total artificial hearts (TAHs), ventricular assist devices (VADs), and orthotopic heart transplants (OHTs) in patients with end-stage heart failure (ESHF) provides several critical insights. Our meta-analysis demonstrated that OHT recipients exhibit superior one-year and five-year survival rates than those receiving TAHs and VADs. Specifically, the one-year survival rate for OHT is 87%, which is significantly higher than the 75% for TAHs and 72% for VADs [4].

Furthermore, quality of life (QoL) scores, assessed via the Kansas City Cardiomyopathy Questionnaire (KCCQ) and the EQ-5D, were highest in OHT recipients, suggesting superior functional and psychological recovery. However, TAHs and VADs have undergone considerable advancements, with improvements in hemodynamic stability and reductions in certain complication rates, positioning them as viable alternatives in the absence of donor hearts [5].

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Finally, quality of life (QoL) scores, assessed via the Kansas City Cardiomyopathy Questionnaire (KCCQ) and the EQ-5D, were highest in OHT recipients, suggesting superior functional and psychological recovery. However, TAHs and VADs have undergone considerable advancements, with improvements in hemodynamic stability and reductions in certain complication rates, positioning them as viable alternatives in the absence of donor hearts (28).

**Implications for Clinical Practice:**

The findings of this review have significant implications for clinical practice. First, while OHT remains the preferred option owing to its superior survival and QoL outcomes, the increasing refinement of TAH and VAD technologies offers promising alternatives for patients who are ineligible for or awaiting transplantation [6]. Clinicians should consider individual patient profiles, including age, comorbidities, and specific device characteristics, to optimise treatment decisions.

Furthermore, the reduction in device-related complications such as thrombosis and infections through advancements in biomaterials and antimicrobial strategies enhances the safety profile of mechanical circulatory support systems [7]. Policymakers should prioritise funding for research and development in artificial heart technologies to address the donor heart shortage and improve patient outcomes [11].

**Strengths and limitations:**

This review's strengths include a comprehensive search strategy, rigorous inclusion criteria, and the use of standardised quality assessment tools, ensuring the reliability of the synthesised data. The incorporation of both randomised controlled trials (RCTs) and observational studies enhances the generalizability of the findings [18]. However, limitations exist, including heterogeneity in study designs, patient populations, and outcome measures, which may introduce bias. Additionally, the lack of long-term follow- up data in some studies limits the ability to assess prolonged outcomes comprehensively [14].

**Comparison with Other Reviews:**

Our findings align with those of previous reviews that highlighted the superior survival rates of OHT over TAHs and VADs. However, this review provides a more nuanced analysis by incorporating recent studies and focusing on QoL outcomes, which have been underreported in earlier reviews [5]. Furthermore, the detailed examination of complication profiles and economic implications distinguishes this review from others, offering a more holistic understanding of the comparative effectiveness of these interventions [8].

**Theoretical and Practical Implications:**

Theoretically, this review underscores the evolving landscape of heart failure management, where mechanical circulatory support systems are progressively bridging the gap left by the scarcity of donor hearts. Practically, the findings advocate for a multifaceted approach to treatment, where patient-specific factors guide the choice between OHT, TAH, and VAD [6].

Economic analysis supports strategic investments in artificial heart technologies, suggesting that long-term cost savings and improved patient productivity could offset initial expenditures [7]. Future research should focus on longitudinal studies to evaluate long-term outcomes and further refine patient selection criteria, ensuring that advances in technology translate into enhanced clinical practice and patient care [1].

**Impact on Practice:**

The findings of this review have profound implications for clinical practice and policy. The demonstrated advancements in TAH and VAD technologies suggest that these devices can be effectively integrated into therapeutic regimens for ESHF patients, especially those ineligibles for or awaiting donor hearts [11]. Clinicians should leverage these insights to personalise treatment plans, considering patient-specific factors such as age, comorbidities, and device characteristics [16].

Additionally, the reduction in complication rates associated with newer TAH and VAD models enhances their safety profiles, making them more attractive options. Policymakers are encouraged to support continued innovation and development in artificial heart technologies, which could address the critical donor heart shortage and improve overall patient outcomes [7].

**Future directions:**

Future research should prioritise longitudinal studies to evaluate the long-term efficacy and safety of TAHs and VADs, providing more robust data on survival and QoL outcomes over extended periods [8]. Investigating the underlying mechanisms that contribute to the observed differences in outcomes between OHT and mechanical circulatory support systems will further refine patient selection criteria and optimise treatment strategies [1].

Additionally, economic evaluations should be expanded to assess the cost-effectiveness of these technologies comprehensively in various healthcare settings, informing resource allocation and policy decisions [16]. Emphasis on patient-reported outcomes and real-world evidence will be crucial in translating these advancements into clinical practice, ultimately enhancing the standard of care for ESHF patients [5].

## Declaration

### Abbreviations

1. **ESHF:** End-stage heart failure
2. **OHT:** Orthotopic heart transplantation
3. **TAH:** Total artificial hearts
4. **VAD:** Ventricular assist devices
5. **QoL:** Quality of life
6. **KCCQ:** Kansas City cardiomyopathy questionnaire
7. **EQ-5D:** EuroQol-5 Dimensions
8. **RCTs:** Randomised controlled trials
9. **NOS:** Newcastle–Ottawa Scale
10. **PRISMA:** Preferred Reporting Items for Systematic Reviews and Meta-Analyses
11. **SD:** Standard deviation

### Ethics approval and consent to participate

None – Not applicable

### Consent for publication

None – Not applicable

### Availability of data and materials

None – Not applicable

### Competing Interests

The authors declare that they have no competing interests.

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### Authors' contributions

All the authors contributed equally to the manuscript. All the authors read and approved the final manuscript.

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