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Surgical Procedures Versus Catheter Intervention in Management of Adult Aortic Coarctation: A Meta-Analysis

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Abstract

Background: Coarctation of aorta refers to constriction of aorta, typically located just distal to left subclavian artery.

Aim of Study: This study aimed to evaluate current literatures for the outcomes of surgery versus catheter intervention in treatment of adult patients of coarctation.

Material and Methods: Systematic review, meta-analysis encompass randomized clinical trials, cohort studies, cross-sectional research. Methodological quality of each study was rigorously evaluated, clarity in outcome measures, appropriateness in statistical analysis to ensure robustness of findings.

Results: A meta-analysis of post-intervention outcomes after aortic coarctation repair found that catheter intervention had significantly lower mortality rates and persistent hypertension compared to surgical repair. Aneurysm formation following catheter intervention was rare, with no heterogeneity. Re-intervention for recoarctation was slightly more common in catheter cases (10%) than in surgical repair (7.6%), with moderate heterogeneity. The findings suggest catheter intervention may be a preferable option due to lower mortality and persistent hypertension, though with a slightly higher need for re-intervention. The study highlights the need for more comprehensive and effective surgical interventions in aortic coarctation repair.

Conclusion: Surgical repair and catheter-based interventions have positive long-term outcomes, but have unique challenges. Surgical repair was related with persistent hypertension, despite fact that it has a higher mortality rate. Catheter-based interventions were less invasive, they were related with a higher risk of aneurysm formation, re-interventions.

Key Words: Adult aortic coarctation – Catheter intervention – Surgical procedures.

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Introduction

COARCTATION of aorta was a condition in which aorta narrows, typically occurring just beyond left subclavian artery **[1].**

Most prevalent cause of aortic coarctation was constriction of aorta in vicinity of patent ductus arteriosus or ductus ligamentum. adjacent region of aorta was believed to be constricted by ductal tissue, which results in a narrowing of aorta's lumen **[2].**

Incidence of aortic coarctation ranges from five-eight percent of all CHD, from 0.2 to 0.6 per 1000 live births. Coarctation was present in fifteen-thirty six percent of cases with Turner syndrome **[3,4].**

There were three distinct forms of coarctation: (a) Preductal coarctation: Narrowing was located in close proximity to ductus arteriosus. Ductus arteriosus was responsible for blood flow to aorta that was distal to narrowing; consequently, severe coarctation can be life-threatening. It was consequence of an intracardiac anomaly that reduces blood flow through left side of heart during embryonic life, resulting in hypoplastic development of aorta. This type was observed in approximately five percent of neonates with Turner syndrome **[4].**

Crafoord, Nylin reported surgical repair of coarctation of aorta for 1st time in 1944. This procedure involved following: Coarctectomy with extended end-to-end anastomosis without cardiopulmonary bypass, coarctectomy with classic end-to-end anastomosis without cardiopulmonary bypass, patch aortoplasty, subclavian patch aortoplasty, coarctectomy with interposition graft using partial cardiopulmonary bypass, transmediastinal coarcitation repair in related with ventricular septal

defect closure. Up until implementation of balloon angioplasty (BA) **[5]**, surgery was sole treatment for CoA.

Aim of the work: This study was to assess current literature regarding effectiveness of catheter intervention versus surgery in treatment of adult cases with coarctation.

Material and Methods

Systematic review, meta-analysis encompass randomized clinical trials, cohort studies, cross-sectional research. The methodological quality of each study is rigorously evaluated, clarity in outcome measures, and appropriateness in statistical analysis to ensure the robustness of the findings.

Types of participants: Human, adults and Patients with aortic cortication.

Types of included interventions: Surgical repair of aortic cortication and bllon angioplasty.

Selection criteria for studies:

Inclusion criteria: English studies and Published studies up to 2024.

Exclusion criteria: Studies on patients <14 years, case reports, audits and review articles.

Methods:

This study compares the surgical repair of aortic coarctation with balloon angioplasty, evaluating multiple clinical outcomes. The primary outcome is the success rate of each intervention. Secondary outcomes include post-intervention mortality and morbidity, specifically persistent hypertension and aneurysm formation. Ventilation and hospitalization duration are also assessed to determine short-term recovery differences. Long-term outcomes were analyzed, including survival beyond five years and the need for reintervention due to re-coarctation. Additionally, the study examines the impact on exercise capacity and postoperative quality of life, providing a comprehensive evaluation of both treatment approaches.

Search strategy for identification of studies:

A thorough search was performed via PubMed, Ovid, Web of Science, Cochrane Library to discover pertinent articles published until December 1, 2024. Search encompassed keywords, MeSH terms pertinent to aortic coarctation, surgical intervention, balloon angioplasty, catheter utilization, mortality, hypertension, aneurysm development, re-coarctation. Reference lists of included publications were examined to identify any pertinent research not discovered by computerized searches.

Additional data collection:

To facilitate a thorough review, complete copies of publications from medical, cardiothoracic surgery journals, together with additional published studies, were acquired. Published case reports, conference proceedings were examined to locate further pertinent studies. Selection of research was based on the pertinence of their title, abstract, and content. This process sought to develop a thorough, detailed synthesis of data to evaluate outcomes of surgical treatments against catheter interventions in therapy of adult aortic coarctation.

Sample size: Up to 2024, all articles that satisfy inclusion criteria.

Ethical considerations: As approved by Committee of University.

Study procedure: Investigation commenced by querying articles utilizing terms ("Aorta"[MeSH Terms] OR "Aorta"[All Fields] OR "Aortic coarctation" [MeSH Terms] OR "Aortic coarctation" [All Fields] OR "Surgical repair" [MeSH Terms] OR "Surgical repair" [All Fields] OR "Balloon angioplasty" [MeSH Terms] OR "Balloon angioplasty" [All Fields] OR "Mortality" [MeSH Terms] OR "Mortality" [All Fields] OR "persistent hypertension" [MeSH Terms] OR "persistent hypertension" [All Fields]) OR "aneurysm formation" [MeSH Terms] OR "aneurysm formation" [All Fields] OR "re-coarctation" [MeSH Terms] OR "re-coarctation" [All Fields], followed by downloading articles that meet inclusion criteria, discarding those that do not satisfy exclusion criterion. Supervisors scrutinized these publications to ensure identification of proper data source. I commenced collaboration with statistical supervisor, inputting data into R-based software for meta-analysis, initiated study.

Search strategy and screening: The search and screening process were directed towards identifying studies pertinent to surgical procedures versus catheter intervention in management of adult aortic coarctation. Duplicates were eliminated, and studies failing to meet the inclusion criteria were excluded. Titles and abstracts were meticulously screened, and subsequently, full texts were assessed for potentially valuable articles.

Participant criteria:

Demographic information, including age, gender, and eligibility criteria for treatment, was collected for all participants. Baseline characteristics such as prior cardiac surgeries, comorbidities, and overall health status were also documented to ensure a comprehensive assessment of patient profiles.

Statistical considerations:

Results from included papers were synthesized utilizing systematic review management software, confirming compliance with established inclusion criteria. A PRISMA flowchart was developed to depict research selection process, specifying quantity of studies examined, evaluated for eligibili-

ty, incorporated into review. Assessment of bias was conducted utilizing Cochrane Collaboration's methodology for randomized clinical trials (RCTs), ROBINS-I for cohort studies, AXIS methodology for cross-sectional research. Relative risk for primary outcomes was calculated by aggregating data, utilizing suitable statistical models, including fixed or random-effects models, depending on observed heterogeneity. Heterogeneity in study was evaluated by I^2 statistics, sensitivity analyses were performed to investigate influence of varying techniques, participant attributes. Publication bias was assessed by funnel plots, Egger's regression test to determine impact of unpublished studies on overall results.

Data extraction: Two independent reviewers systematically extracted data in accordance with PRISMA guidelines. Utilizing a standardized data extraction tool and Microsoft Excel, details such as participant demographics, surgical procedures, type of intervention, and outcomes were extracted. Authors of included studies were solicited for more information as required. data extraction technique was thorough, guaranteeing complete gathering of pertinent data, encompassing baseline characteristics, outcomes of each study.

Data synthesis: Data were synthesized in a meta-analysis using RevMan V5.4. Binary data, such as incidence of treatment success and complications, were analyzed using relative risk or odds ratios. Continuous variables like length of hospital stay were assessed using mean weight differences. Results were presented with 95% confidence intervals, and for studies using random-effects models, prediction intervals were included. Sensitivity, subgroup analysis were performed to evaluate robustness of findings, investigate specific outcomes. Statistical heterogeneity was evaluated using $\chi 2$ and I2 tests, with funnel plots used to assess publication bias when appropriate.

Evaluating the level of certainty in the findings: The GRADE approach was utilized to evaluate the certainty of the evidence. A Summary of Findings (SoF) table was created, including essential information like absolute risks for treatment and control groups, relative risk estimations, and the quality of evidence, considering factors such as bias risk and precision.

Handling missing data: Missing standard deviations were estimated using available standard errors or 95% confidence intervals. Continuous outcomes were combined using mean differences or standardized mean differences, and dichotomous outcomes were synthesized using relative risk, employing a random-effects approach to accommodate clinical and methodological variability. Heterogeneity was assessed through forest plot examination and chi-square and I^2 tests, with sensitivity analyses performed for trials influencing the uniformity of combined estimates.

Evidence of publication bias: Publication bias was evaluated by funnel plots, especially when meta-analysis comprised ten or more studies. PRISMA flowchart delineated study selection procedure, risk of bias for each study was assessed utilizing Cochrane collaboration tool, ROBINS-I, AXIS tool. Subsequent to data aggregation, relative risk for each designated outcome measure was computed, analyzed.

Results

The majority of our research were retrospective cohort, only one randomized clinical trial, with wide geographical distribution, our total sample size 739 individuals with mean age ranged from 14 to 50 years old.

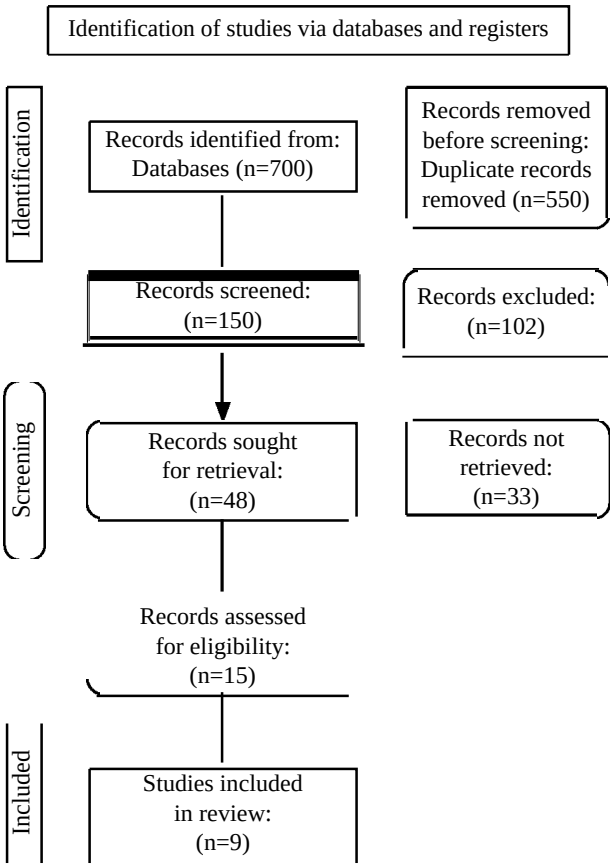

Fig. (1): PRISMA flow diagram for study selection process.

Risk of bias, quality of included RCTs were evaluated using ROB1 method. Our included cohort studies were assessed using NIH tool quality of our cohort ranked from good to fair Quality.

Outcomes:

Early post intervention mortality:

As regard post intervention mortality after repair of aortic coarctation was assessed among 540 patients our pooled meta-analysis for surgical repair

showed prevalence of 12.2% and 95% CI; [0.02, 0.18]. however, catheter intervention was assessed among 165 patients pooled prevalence for mortality from Catheter intervention was 6% and 95% CI; [0.007,0.1]. So Catheter intervention was significantly lower mortality. Heterogenity was detected among our pooled studies with chi- $p<0.001$ and I^2 87% (Fig. 3).

Post intervention morbidity:

Persistent hypertension:

As regard post intervention persistent hypertension it was assessed among 267 patients our pooled meta-analysis showed pooled prevalence for surgical repair 32.9% and 95% CI; 0.3 [0.18, 0.41]. However, catheter intervention was assessed among 91 patients pooled prevalence for it 16.4% and 955CI; 0.14 [0.016, 0.27]. Catheter intervention was significantly lower persistent hypertension than surgical intervention, major heterogenity was detected among our pooled studies with chi- $p<0.001$ and I^2 95%. (Fig. 4).

Aneurysm formation:

As regard post intervention Aneurysm Formation our pooled meta-analysis for catheter intervention was 186 patients showed prevalence 2.1% and 95%CI; [0.003, 0.047]. No heterogenity was detected among our pooled studies so our pooled studies for this outcome were homogenous with chi- $p<0.8$ and I^2 0%. (Fig. 5).

Re-intervention for recoarctation:

Regarding Re-intervention for recoarctation was assessed among 218 patients our pooled meta-analysis for catheter intervention showed prevalence 10% and 95% CI; [0.014, 0.13]. However, for surgical repair it was assessed in 273 cases with pooled prevalence 7.6% and 95 & CI [0.04, 0.12]. Moderate heterogenity was detected among our pooled studies for this with chi- $p<0.001$ and I^2 74%. (Fig. 6).

Table (1): Gives comprehensive baseline & summary characteristics of our selected population.

Study ID	Study design	Sample Size	Site	Age	Weight	Duration of follow-up	Informed concent	Male	Female	Bicusped aortic valve	VSD	ASD	Cardiac diseases
Bauer [6]	Retrospective cohort	15	Germany	50 to 63	NR	4y	0	NR	NR	0	0	0	0
EBEID [7]	Retrospective cohort	9	Mississippi	14 to 63	47 to 133Kg	4y	9	2	7	0	0	0	2
Hager [8]	Retrospective cohort	273	Germany	16 to 73	NR	10y	273	184	89	0	0	0	3
Johnston [9]	Retrospective cohort	32 (14F/18M)	Texas	15.2	52.4Kg	1.5y	32	18	14	0	0	0	5
Ledesma [10]	Retrospective cohort	54 (35M/19F)	Mexico	22±9	NR	3y	0	35	19	0	0	0	8
Lezo [11]	Retrospective cohort	73 (46M/27F)	Spain	20±12	NR	2y	73	46	27	0	2	0	4
Toro-Salazar [12]	Retrospective cohort	252	Minnesota	30 to 50	NR	3y	0	NR	NR	0	1	0	25
Tyagi [13]	RCT	21	India	18 to 61	NR	2y	0	NR	NR	0	0	0	3
Walhout [14]	Retrospective cohort	29	The Netherlands	15 to 71	NR	3y	29	NR	NR	12	2	1	2

NR: Not reported.

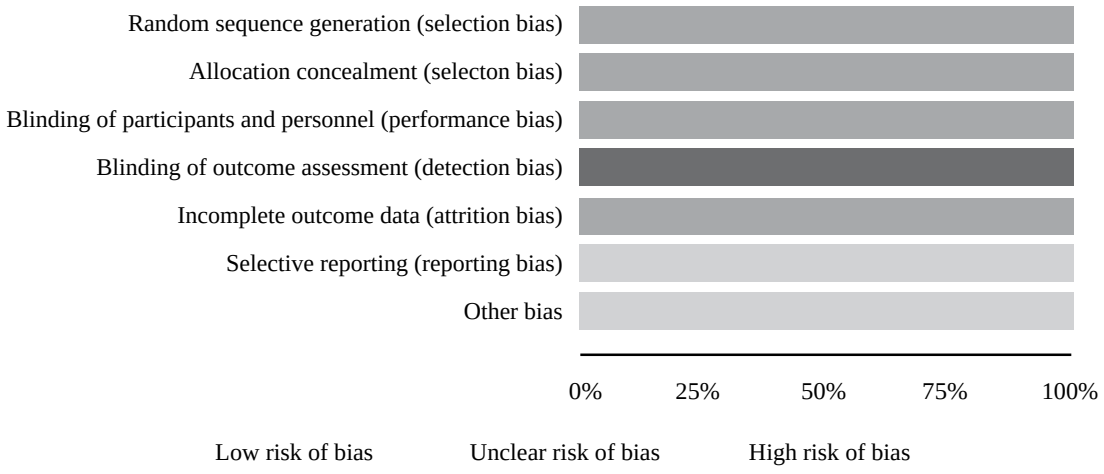

Fig. (2): Risk of biasgraph.

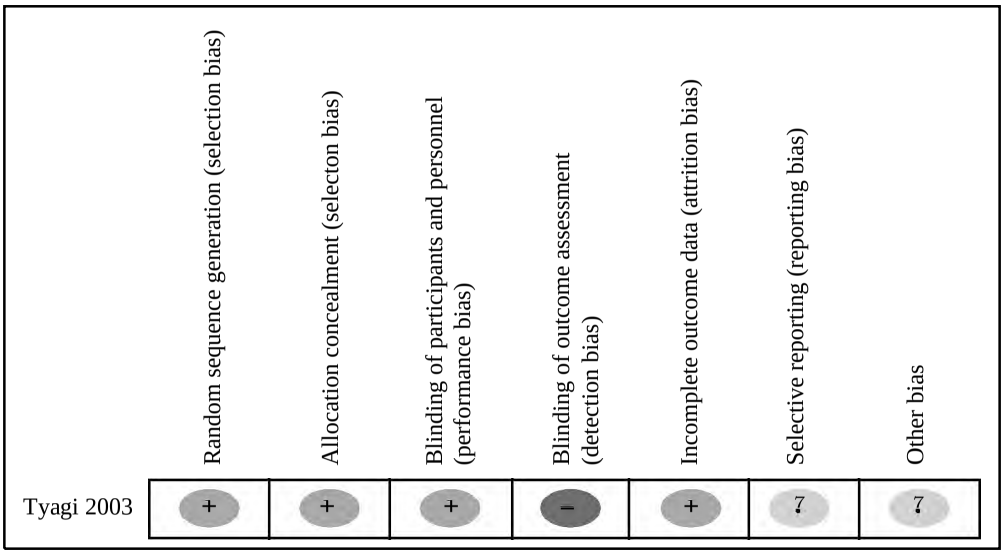

Table (2): Risk of biassummary.

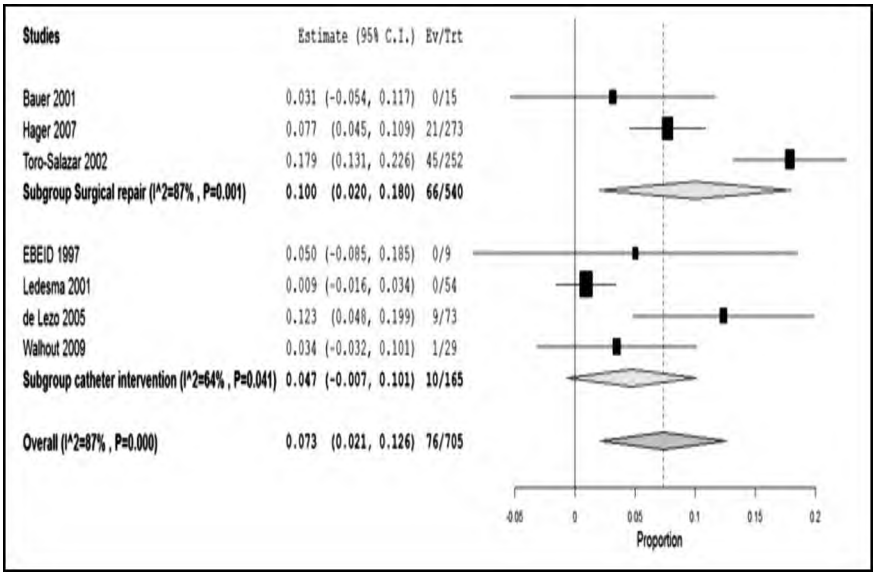

Fig. (3): The forest plot for Early Post intervention mortality.

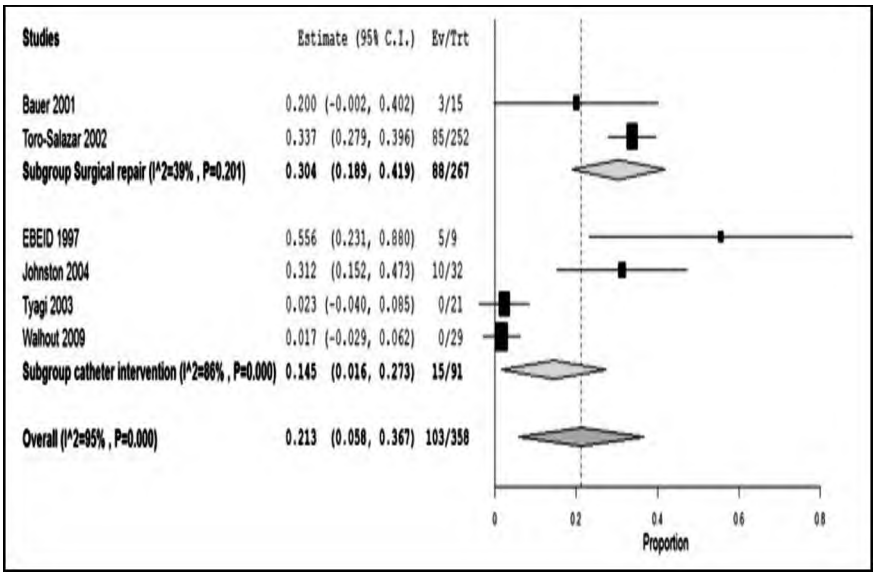

Fig. (4): Shows forest plot for persistent hypertension.

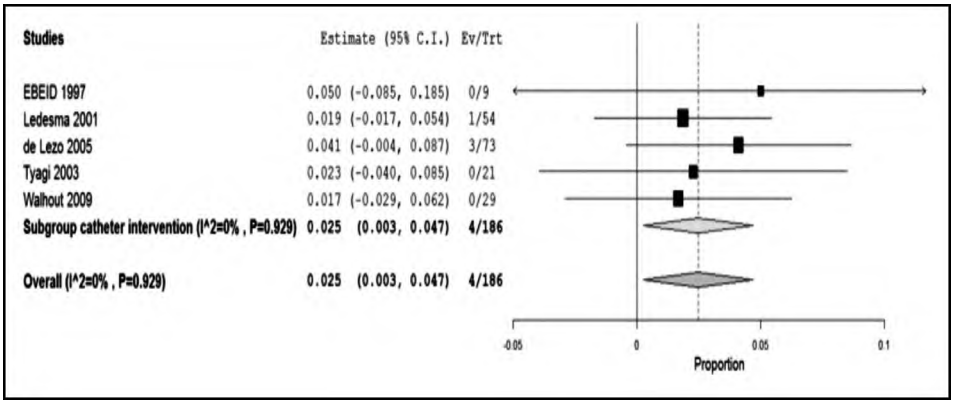

Fig. (5): Shows forest plot for post intervention Aneurysm Formation.

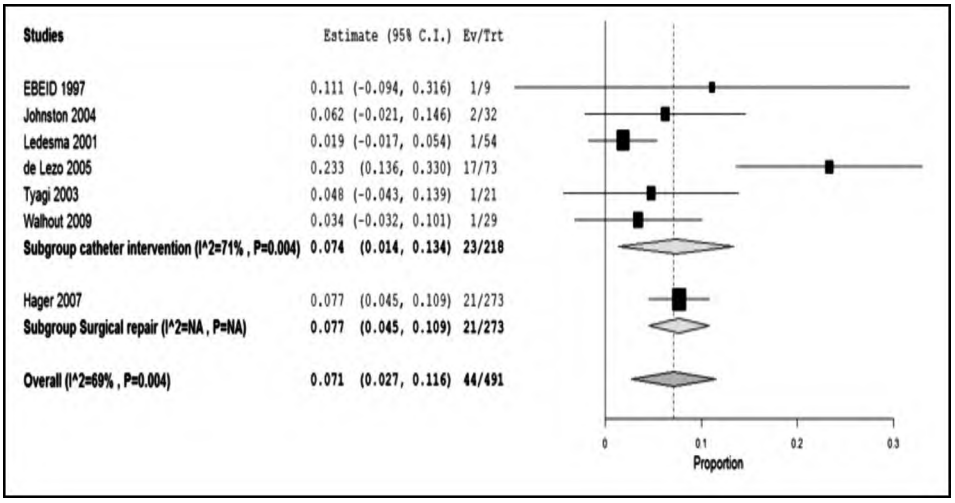

Fig. (6): Forest plot for re-Intervention for recoarctation.

Discussion

Our systematic review and meta-analysis included nine studies, majority of our studies were retrospective cohort and only one randomized clinical trial, with wide geographical distribution, our total sample size 739 individuals with mean age ranged from 14 to 50 years old.

Risk of bias assessment:

Quality of our included cohort studies, judged using NIH methodology, ranged from good to fair.

Outcomes:

As regard post intervention mortality after repair of aortic coarctation:

In a pooled meta-analysis involving 540 cases, prevalence of surgical repair was determined to be 12.2 percent with a ninty five percent confidence interval of [0.02, 0.18]. Among 165 cases analyzed, pooled prevalence for mortality due to catheter intervention was six percent, with a ninty five percent confidence interval of [0.007, 0.1]. Heterogeneity was seen among our aggregated research, with a chi-square *p*-value of less than 0.001 & an I^2 statistic of eighty seven percent.

Bauer et al. **[6]** sought to evaluate long-term outcomes of surgical repair for aortic coarctation in fifteen percent over age of fifty, discovered that there were no instances of early or late mortality or neurological problems following surgery.

Walhout et al. **[14]**, who sought to assess long-term outcomes of balloon angioplasty for coarctation in adults, discovered that no procedure-related problems or mortality occurred.

Toro-Salazar et al. **[12]** reported that operative correction of simple coarctation was conducted on 274 cases, with 252 surviving; of these, forty five succumbed at a mean age of 34.4±22.1 years. Ninety-five percent of cases survived at ten years, eighty nine percent at twenty years, eighty two percent at thirty years, seventy nine percent at forty years post-operation. Age at initial surgical intervention significantly influenced long-term survival, with lowest mortality rates noted in cases who had surgery between one, five years of age.

According to Nana et al. [15], who sought to evaluate technical success, re-intervention, mortality following stenting for CoA in adults, mortality rates were one percent at thirty days ,two percent at midseason. Data from cases treated for CoA with open repair indicated comparable outcomes regarding early mortality. Prior analyses comparing standard angioplasty, open repair determined that angioplasty was advantageous regarding early mortality, morbidity, although related with an increased incidence of re-coarctation, aneurysm formation.

Regarding post intervention persistent hypertension:

Among 267 patients our pooled meta-analysis showed pooled prevalence for surgical repair 32.9%; 0.3 [0.18, 0.41], however catheter intervention was assessed among 91 patients pooled prevalence for it 16.4% and 955CI; 0.14 [0.016, 0.27]. major heterogenity was detected among our pooled studies with chi- $p<0.001$ and I^2 95%.

Conformity Carr et al. [16] aimed to evaluate benefits, risks of angioplasty, stenting in comparison to surgical repair to determine optimal option for cases. They found that morbidity related with stenting ranged from zero percent to twenty percent (mean nine percent), while morbidity for angioplasty ranged from forteen percent to twenty four (mean nineteen percent). Morbidity range for combination therapy involving angioplasty, stenting was seventeen to twenty two percent, with a mean of nineteen percent.

Bauer et al. [6] found that, during follow-up examinations after surgical repair, only three cases had mild hypertension at rest, while remaining twelve cases were normotensive.

Johnston et al. [9], who performed transcatheter balloon dilation therapy, observed a reduction in peak-to-peak systolic gradient across coarctation during catheterization in all cases; mean peak-to-peak systolic gradient decreased from thirty one to 1.7mm Hg, which was statistically significant (p=0.001).

Tyagi et al. [13] demonstrated that hypertension alleviated promptly following stent insertion. During long-term follow-up, twenty out of twenty one cases (95.2 percent) exhibited improvement in hypertension. mean systolic blood pressure reduced from 178.0±24.5mm Hg to 138.0±8.2mm Hg (p<.001).

As regard post intervention aneurysm formation:

Our pooled meta-analysis for catheter intervention was 186 patients showed prevalence 2.1% and 95%CI; [0.003, 0.047]. No heterogenity was detected among our pooled studies so our pooled studies for this outcome were homogenous with chi- $p<0.8$ and I^2 0%.

Regarding Bauer et al., [6] They found that in adults, utilization of balloon angioplasty, stent implantation in cases with coarctation carries a significant risk of aneurysm formation, aortic rupture. In this cases cohort, catheter dilation was indicated for cases of postsurgical recoarctation, for individuals with localized coarctation.

De Lezo et al. [11] observed that there were no incidences of restenosis or aneurysm formation in adult group treated with balloon angioplasty.

Regarding Re-intervention for recoarctation:

Among 218 patients our pooled meta-analysis for catheter intervention showed prevalence 10% and 95% CI; 0.074 [0.014, 0.13]. However, for surgical repair it was assessed in 273 cases with pooled prevalence 7.6%; 0.07 [0.04, 0.12]. Moderate heterogenity was detected among our pooled studies for this with chi- $p<0.001$ and I^2 74%.

Accordance Hager et al., [8] objective was to evaluate prevalence of hypertension through a comprehensive cross-sectional study of all cases undergoing long-term follow-up post-coarctation repair, to delineate impact of surgical data, current restenosis. They reported that twenty nine cases (eleven percent of 273-cases study group) had undergone reinterventions. Sixteen cases underwent recurrent surgeries, twelve received balloon angioplasty, one cases had a stent placed. Of twenty nine cases, five necessitated a 2^{nd} reintervention (comprising three balloon angioplasties, two stent placements), whereas 1 cases underwent a 3^{rd} reintervention (surgical intervention).

Conclusion:

Both surgical repair and catheter-based interventions show favorable long-term outcomes, but with distinct advantages and challenges. Surgical repair may carry a slightly higher mortality rate but is associated with a higher rate of persistent hypertension. Catheter-based interventions tend to be less invasive but are linked to a higher risk of re-interventions and aneurysm formation. These findings suggest that patient selection and individualized treatment plans are crucial for optimizing outcomes, with careful consideration of the risks associated with each approach.

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الإجراءات الجراحية مقابل التدخل بالقسطرة فى علاج تضيق الشريان الأورطى لدى البالغين: تحليل تلوى

الخلفية: تضيّق الأبهر هو حالة مرضيه تتسم بتضيّق غير طبيعى فى جزء من الشريان الأبهر.

الهدف من الدراسه: تهدف هذه الدراسة إلى تقييم الأدبيات الحالية لنتائج الجراحة مقابل التدخل بالقسطرة فى علاج مرضى تضيق الشريان الأورطى البالغين.

المواد وطُرق الدراسه: شملت المراجعة المنهجية وتحليل التجارب السريرية العشوائية، ودراسات المجموعات، والدراسات المقطعية. تم تقييم الجودة المنهجية لكل دراسة بشكل دقيق، مع التركيز على وضوح معايير النتائج، وملاءمة التحليل الإحصائى لضمان قوة النتائج.

النتائج: أظهر التحليل لنتائج ما بعد التدخل بعد إصلاح تضيق الشريان الأورطي أن التدخل بالقسطرة أظهر معدلات وفاة أقل بشكل كبير وارتفاع ضغط الدم المستمر مقارنةً بالإصلاح الجراحى. كما كانت حالات تكون التمدد الشريانى بعد التدخل بالقسطرة نادرة، مع عدم وجود تباين كبير بين الدراسات. كان إعادة التدخل بسبب تضيق الأورطى مرة أخرى أكثر شيوعًا قليلاً فى حالات القسطرة (١٠٪) مقارنةً بالإصلاح الجراحى (٧,٦٪)، مع تباين معتدل. تشير النتائج إلى أن التدخل بالقسطرة قد يكون خيارًا مفضلاً بسبب انخفاض معدلات الوفاة والضغط الدموى المستمر، على الرغم من الحاجة الأعلى قليلاً لإعادة التدخل. تبرز الدراسة الحاجة إلى تدخلات جراحية أكثر شمولية وفعالية فى إصلاح تضيق الشريان الأورطى.

الخلاصة: تتمتع كل من الإصلاح الجراحي والتدخلات المعتمدة على القسطرة بنتائج طويلة الأمد إيجابية، لكنهما يواجهان تحديات فريدة. الإصلاح الجراحى مرتبط بمعدل وفيات أعلى لكنه مرتبط بارتفاع ضغط الدم المستمر. تدخلات القسطره أقل تدخلاً، لكنها تحمل خطرًا أعلى لإعادة التدخل وتكون التمددات الشريانية.