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Systematic Review and Meta-Analysis of Surgical Versus Non-Surgical Management for Varicocele: Comparative Evaluation of Fertility Outcomes and Complication Rates

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ABSTRACT

Varicocele is a condition causing abnormal dilatation of the pampiniform plexus in the scrotum, affecting spermatogenesis, testicular volume, semen parameters, fertilization, implantation, and embryonic outcomes. This systematic review and meta-analysis aimed to compare surgical and non-surgical management of Varicocele, evaluating fertility outcomes and complication rates, synthesizing clinical studies for effectiveness and safety. The methodology includes the systematic review of 26 studies and a meta-analysis of 16 studies, followed by the search strategy, data extraction, inclusion and exclusion criteria, data analysis, and data extraction strategy of the included selected studies. For the criteria of study selection, PRISMA chart has been created to review the selection process of included studies. Research indicates that undergoing surgery to cure varicocele enhances the likelihood of conception, sperm quality, live birth rates, and success of sperm retrieval. Varicocele embolization is one non-surgical treatment that provides rapid pain relief, minimum invasiveness, and a quicker recovery. Antioxidants can enhance sperm parameters and conception rates when combined with other treatments. Reproductive outcomes are improved by varicocele repair, which includes surgical and angiographic embolization. This procedure lowers sperm DNA fragmentation. For males with varicocele, surgery is still the major way to improve quality of life. It was concluded that Varicoceleectomy is the primary fertility treatment for men with varicocele, offering significant benefits in pregnancy rates, sperm parameters, and long-term results, while non-surgical approaches offer faster recovery and minimal invasiveness.

INTRODUCTION

Varicocele, a condition characterized by abnormal dilatation or tortuosity of the pampiniform plexus in the scrotum, affects 15% of men in general, 35% of men who are infertile first, and 80% of men who are infertile again. The pathogenesis is multifactorial, with incompetent venous valves and anatomic variations in venous drainage between the left and right internal spermatic veins leading to venous reflux and elevated hydrostatic pressure. Physical activity in adolescence can cause Varicocele development, and physical activity in later life can exacerbate the illness (Alsaikhan *et al.*, 2016). Anatomical variables including a longer left spermatic vein, the absence of a valve, the "nutcracker phenomenon", increased blood flow and pressure, and developmental factors like puberty and adolescence all have an impact on the development of Varicocele. Tobaccos age, renal arteriovenous malformations, deep vein thrombosis, and pampiniform plexus thrombosis are further uncommon causes (Su *et al.*, 2021).

Spermatogenesis, testicular volume, semen parameters, fertilization, implantation, and embryonic outcomes are all adversely affected by Varicocele (Hassanin *et al.*, 2018). Although Varicocele are common in sub-fertile males, there is ongoing discussion on their effects on live birth rates and fertility treatments. The possible impacts on sperm DNA fragmentation and semen parameters are of concern. Treatment is an intrusive, costly procedure with some side effects, but it may increase semen parameters, fertility, and pregnancy rates (Maheshwari *et al.*, 2022).

Oxidative stress is a major element in the difficult issue of Varicocele-induced fertility. The usual course of treatment is still microsurgical Varicoceleectomy; antioxidant supplements plus Varicoceleectomy may enhance the success of pregnancy outcomes (Su *et al.*, 2021). Varicocele has been linked to an elevated risk of specific health issues. Notably, men with asymptomatic Varicocele did not exhibit an increased risk of heart disease, diabetes, or hyperlipidemia post-diagnosis. In contrast, individuals with symptomatic Varicocele were found to have a greater likelihood of developing these conditions (Wang *et al.*, 2018).

Rationale for comparing surgical and non-surgical management options

Blocking the vein to reroute blood flow is the surgical treatment for Varicocele. Open surgery or minimal invasive techniques such as laparoscopic or microscopic Varicoceleectomy are available

options. In males with palpable Varicocele and low-quality sperm, Varicocele repair can increase fertility and pregnancy rates by 13-51%.

While non-surgical method called Varicocele embolization can be used to treat Varicocele without requiring open surgery. It has benefits including a quicker recovery period, local anesthetic, a lower chance of complications, and a quicker return to normal activities.

The objective of this present systematic review and meta-analysis is to comprehensively evaluate and compare the fertility outcomes and complication rates associated with

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surgical and non-surgical management of Varicocele. This review aimed to synthesize existing evidence from clinical studies to provide a robust analysis of the effectiveness and safety of these management strategies in improving fertility outcomes among patients with Varicocele.

MATERIALS & METHODS

Search Strategy & Key Words

The review was carried by using the current research and review publications available in Google Scholar, PubMed, NCBI, Scopus, Web of Science, Medscape, and Springer based on the evaluation and comparative analysis of fertility outcomes rates associated with the surgical and non-surgical management of varicocele. From the beginning January to the April 2024, a thorough search of the literature on the was done to obtain the comprehensive results by using the keywords including "Surgical treatment of Varicocele", "Varicocele embolization", "Varicocele effects fertility", "Varicocele impacts sperm viability", and "Varicocele embolization improves fertile".

The given criteria were required for eligibility; i) Determination of fertility rates improved after either surgical or non-surgical treatment of varicocele; ii) Comparison of effectiveness resulted from surgical and non-surgical varicocele treatment; iii) Sperms morphological improvement after embolization) studies from randomized control trials; iv) Model dimensions of less than 10 participants; v) English morphological; and vi) Availability of complete text. PRISMA guidelines have been followed as a standard for writing systematic and meta-analyses.

Initially, a comprehensive search yielded a total of 4635 articles (databases and register included). To refine the research and focus on the relevant literature, specific filters were applied, such as year of publication, the field of study, article type and studies related to Varicocele effective management. The collection of data approach used precise combinations

and variants of search terms such as "Varicocele"; "Fertility Outcomes"; "Complication rates"; "Infertility in Varicocele"; and "Meta-analyses". To ensure an in-depth search, terms such as "Varicocele Pathophysiology"; "Varicoceleectomy"; and "Pregnancy rates"; were included. The final dataset included 456 records for additional analysis and inclusion in the systematic review and meta-analysis, which included the most relevant and recent studies.

Inclusion and Exclusion Criteria

Inclusion Criteria

In addition to abstracts focused on relevance, the following inclusion and exclusion criteria were used as a second-hand filter on titles. We only considered research that have been submitted to and accepted by peer-reviewed journals, even though we searched the Grey literature. The inclusion criteria were established based on Cochrane recommendations.

- Randomized, non-randomized control trials and cohort studies were included for comparing surgical and non-surgical management of varicocele.
- Include studies involving adult male patients diagnosed with varicocele. Studies were included evaluating any surgical intervention for varicocele.
- Studies included data on post-operative complications related to surgical interventions (e.g., infections, hematoma, testicular atrophy) and complications associated with non-surgical management.
- Studies in English language were included to ensure the comprehensive coverage.
- Abstracts were also considered for inclusion into this review because contrary to the typical recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol, experience in the beneficial use of abstracts allows for their inclusion for systematic review, provided that the relevant data (e.g., total sample population, group sample sizes, and treatment outcomes) needed for the analysis are indicated in the abstract.

Exclusion Criteria

- Studies published in languages other than English were excluded due to potential languages barriers that could impact data interpretation and inclusion.
- Studies without comparative analysis between surgical and non-surgical management for varicocele were excluded, including those solely investigating medical management without a comparison to surgical interventions.
- Studies involving animals or non-human subjects were excluded due to potential limitations in translating their outcomes directly to human contexts.
- Studies lacking a comparative design, such as case reports, case series or those without a control group, were excluded from the analysis.
- Studies that do not report relevant outcomes such as fertility parameters (e.g., sperm quality, pregnancy rates) and complications rates (e.g., recurrence rates, postoperative complications) were excluded from the analysis.

Data Extraction

This review focuses on the comparative evaluation of fertility outcomes after the surgical and non-surgical treatment of Varicocele in humans, specifically between the age of 20 to 50 years of married man. A comprehensive search of 4565 articles was conducted from February 2018 to March 2024, using terms like "Surgical treatment of Varicocele", "Varicocele embolization", "Varicocele effects fertility", " Varicocele impacts sperm viability" and " Varicocele embolization improves fertile". Abstracts were independently evaluated and scrutinized the entire text for eligibility. PRISMA guidelines were followed for systematic analysis and meta-analysis. The final dataset included 54 records for further analysis, including the most relevant and recent studies.

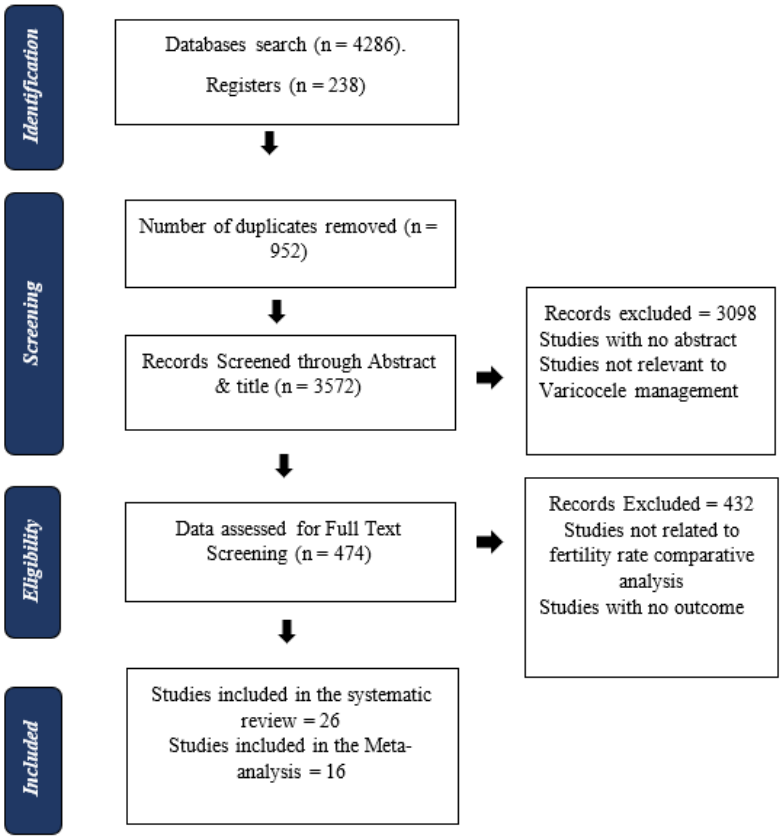


Figure 1: Prisma flow chart

The identification of studies involves multiple stages, with the final selection based on specific criteria. The initial identification process involves removing duplicate records, screening 3572 records, excluding 3098 records, and assessing 474 full-text articles for eligibility. Out of these 432 records were excluded as they were not related to fertility rate comparative analysis.

The remaining 42 records are for qualitative analysis. Quantitative analysis (meta-analysis) includes 14 studies, and the review includes 28 selected studies. The total number of selected studies was determined by meeting inclusion criteria and passing through the screening, full-text assessment, and quantitative analysis stages, leading to the final selection of relevant and suitable studies for the review.

Data Analysis

Our preliminary search included articles from three previously chosen credentials to validate our search method and ensure these publications were retrieved and selected.

The observational research was assessed using the ROB criteria, and the quality of the included studies was assessed using the "Quality Assessment of Diagnostic Accuracy Studies (QUADAS)" questionnaire, which was utilized to conduct a thorough risk of bias evaluation. Four main areas were examined in the evaluation: flow and timing, reference standard, index test, and patient selection.

All estimates and 95% certainty intervals were used to create a forest plot and funnel plot. The instantaneous estimations of disorientation existence were calculated using random-effect models due to the anticipated variability in the available datasets. To check for heterogeneity, forest plots were analyzed quantitatively and qualitatively.

Risk of Bias Assessment

The study discusses the risk of bias associated with the methodology of using surgical and non-surgical management of Varicocele for predicting comparative outcomes of fertility in male patients:

- Researchers acknowledge that the method has shortcomings, particularly in estimating the inception level of the fertility rate for predicting outcomes.
- To maximize predictive efficacy and to mitigate the rate biasness in the treatment, systematic differences between the groups being compared (surgical vs. non-surgical management) were assessed.
- These factors should be considered and incorporated into logistic regression models to mitigate bias associated with their strong correlation with poor outcomes.
- The assessment of biomarkers at various time points and the measurement of numerous outcomes can exacerbate the risk of bias.
- In this review, the assessment of potential biases were critical components of the methodology. Quality Assessment of Diagnostic Accuracy Studies (QUADAS) is

a diagnostic test accuracy tool that can evaluate the risk of bias in comparative accuracy studies (Cochrane methods of QUADAS-C Tool, 2022). Reviewers independently assessed the Risk of Bias using the modified QUADAS questionnaire. Each study was evaluated on four critical domains: "Patient Selection, Index Test, Reference Standard, and Flow and Timing".

RESULTS AND DISCUSSION

Varicocele is a major cause of male infertility, affecting 15% of the general male population and 35% of men with infertility. Treatment aims to enhance sperm parameters and fertility outcomes, with decisions based on factors like Varicocele size, fertility goals, and symptoms. Several studies suggest that surgical treatment, particularly microsurgical Varicoceleectomy, has the highest rate of improvement in sperm parameters and pregnancy rates. Open surgical repair is recommended, but risks include complications like hydrocele, Varicocele recurrence, infection, and chronic testicular pain. Non-surgical management, such as dietary supplements, may also be considered (Ouanes *et al*., 2022; Persad *et al*., 2021).

Study Selection

A concise systematic review and meta-analysis were performed to identify and evaluate pertinent studies regarding the comparative management and fertility outcomes of patients with Varicocele who underwent surgical and non-surgical treatments.

To identify all relevant studies published in the past 10 years, an exhausted search of electronic databases was carried out. The process for selecting precise and relevant studies to access biomarker accuracy is depicted in Figure 2.

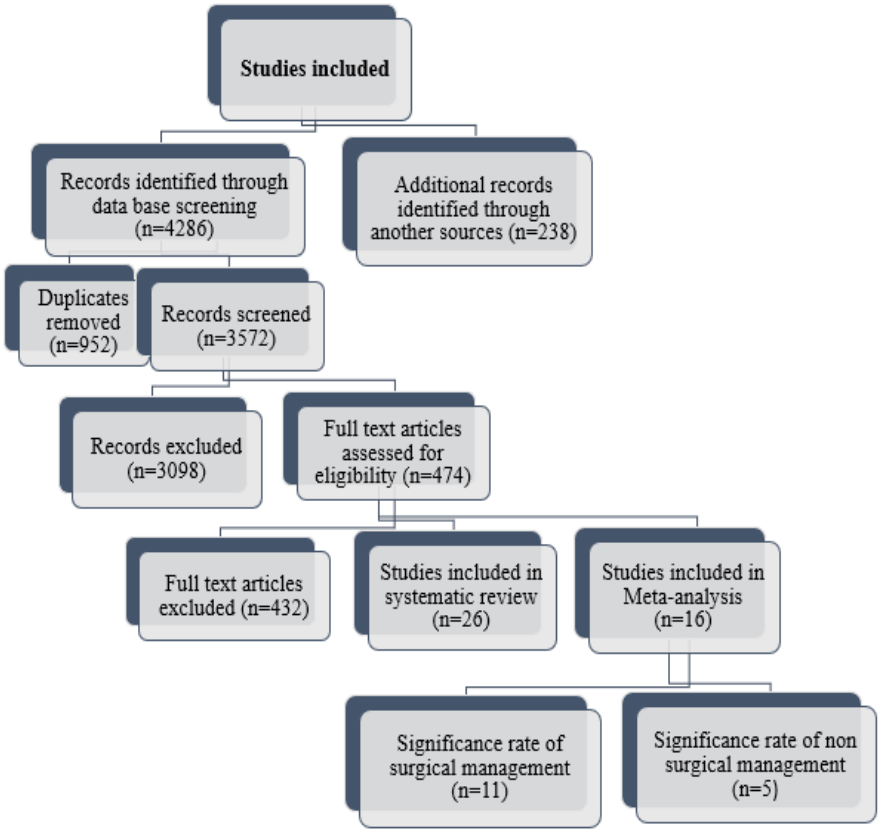


Figure 2: Flow Chart of Selected Studies for Meta-Analysis

The flow chart depicts the study selection process for the meta-analysis. A total of 4286 records were identified through database searching, and an additional 238 records extracted through other sources. After removing duplicates (952), a total of 3,572 records underwent screening. Among these, 3098 records were excluded, leaving 474 full-text articles for eligibility assessment. Ultimately, 432 full-text articles were excluded, resulting in 28 articles included in systematic review. Among these, 14 papers were also part of the meta-analysis. The comparative analysis of fertility rate outcomes was conducted across surgical and non-surgical management approaches.

Characteristics of Included Studies

Among 16 randomized controlled trials, 11 studies documented favorable fertility outcomes, while a smaller subset 5 studies investigated non-surgical treatments, showing less positive outcomes for Varicocele patients or detailing Varicocele treatment approaches. The study participants were adults with ages spanning from 20 to 70 years on average. Patients cited reasons for evaluating Varicocele treatments included overcoming infertility and increasing pregnancy rates, attributing successful outcomes to these interventions.

Risk of Bias Assessment Results

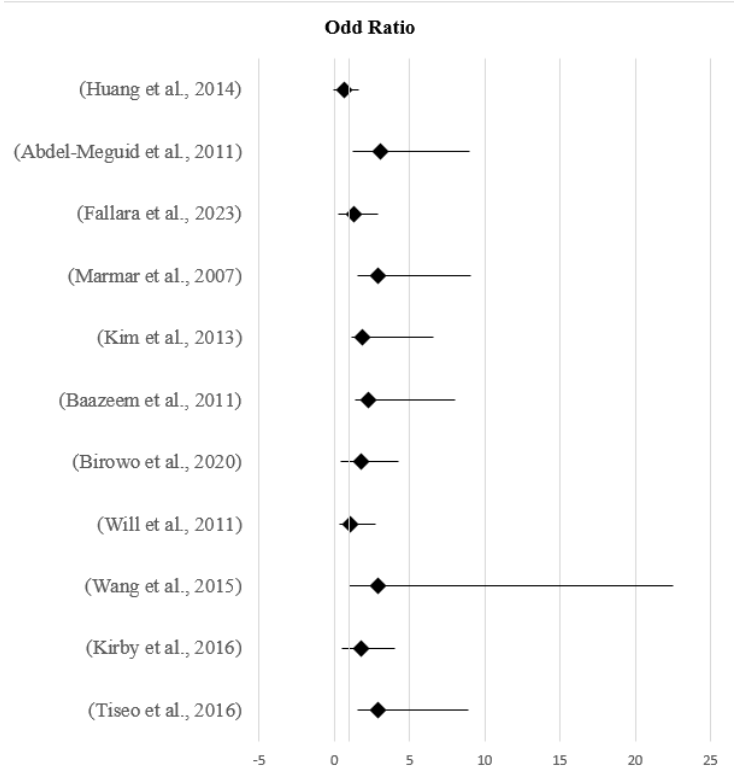
In the meta analysis, assessing potential biases using the modified QUADAS questionnaire yielded favorable results. Each study underwent thorough scrutiny across four crucial domains including patient selection, index test, reference standard, flow and timings by impartial reviewers. This rigorous evaluation process indicated minimal risk of bias in most studies, highlighting strong methodology in assessing both surgical and non-surgical management for predicting fertility outcomes in varicocele patients. Utilizing data dependent threshold calculation and logistic regression models, researchers effectively demonstrated the significant benefits of Varicoceleectomy in improving sperm quality and morphology, reducing infertility complications. These findings underscore the reliability and validity of the meta-analysis in evaluating Varicoceleectomy efficacy for Varicocele effected patients.

Comparison of the Efficacy of Surgical and Non-Surgical Management of Varicocele

A meta-analysis was conducted to evaluate the treatment efficacy for Varicocele associated infertility. Forest plots were generated to provide a visual summary finddings from two comparative studies. These plots display the Odds Ratios (OR) and their corresponding 95% confidence intervals (Cl) for each study, alongside the pooled OR and Cl for both studies. The horizontal line at OR=1.0 represents no association between treatment type and fertility rates. An OR greater than 1.0 suggests a positive association, while OR less than 1.0 indicates a negative association. The width of the confidence interval reflects the precision of the estimate, with wider intervals lower precision, as illustrated in Table 1.

Table 1: Forest Plot Of Selected Studies Indicating Surgical Management Outcomes

Studies	Odd Ratio	Lower Confidence level	Upper confidence Level
(Huang et al., 2014)	0.70	0.76	0.92
(Abdel-Meguid et al., 2011)	3.04	1.84	5.98
(Fallara et al., 2023)	1.29	1.00	1.65
(Marmar et al., 2007)	2.87	1.33	6.2
(Kim et al., 2013)	1.9	0.77	4.66
(Baazeem et al., 2011)	2.23	0.86	5.78
(Birowo et al., 2020)	1.82	1.37	2.41
(Will et al., 2011)	1.1	0.73	1.68
(Wang et al., 2015)	2.9	1.92	19.6
(Kirby et al., 2016)	1.76	1.267	2.284
(Tiseo et al., 2016)	2.87	1.33	6.02



Analysis of Surgical Management to Compare Improved Fertility Outcomes

The provided studies offer compelling evidence that surgical Varicocele treatment, known as Varicoceleectomy can significantly improve fertility outcomes in men with varicocele and abnormal semen parameters. (Abdel-Meguid *et al*., 2011; Fallara *et al*., 2023; Huang *et al*., 2014) demonstrated improved pregnancy rates for couples where the male partner undergoes varicocele repair. Odds ratio range from 1.29 to 3.04, indicating a 29% to 304% increase in pregnancy.

Varicoceleectomy improves sperm concentration, motility and morphology. This improvement was observed in men with severe conditions like azoospermia (no sperm in semen), while showed a69% high success rate of surgical retrieval after varicocele treatment for use in IVF (Abdel-Meguid *et al*., 2011; Baazeem *et al*., 2011; Huang *et al*., 2014).

(Abdel-Meguid *et al*., 2011; Birowo *et al*., 2020) reported a significant increase in live birth rates following varicocele repair, with odds ratio up to 2.80, translating to a 180% higher chance of live birth. Durable improvement (microsurgical Varicoceleectomy) offers a long lasting solution, showed sustained improvement in semen parameters for up to 12 months' post-surgery.

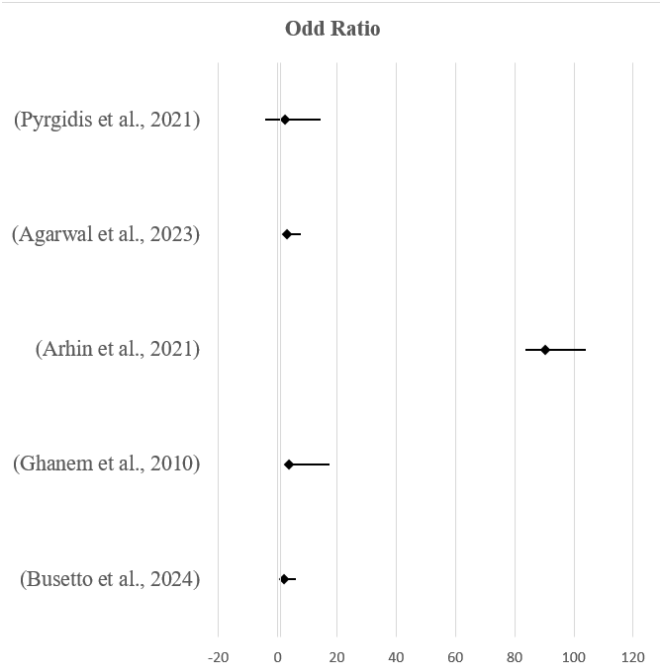
It is important to note that the most significant benefits were seen in men with clinically detectable varicocele and abnormal semen analysis. (Baazeem *et al*., 2011; Kim *et al*., 2013; Tiseo *et al*., 2016) showed that men with subclinical varicocele or normal semen parameters may not experience the same level of improvement.

Preoperative factors including age and baseline sperm density can influence the success of Varicoceleectomy, (Huang *et al*., 2014) suggest that younger patients and those with higher baseline sperm density tend to have better outcomes.

Suggest that microsurgical approaches like inguinal or sub inguinal may offer advantages over traditional open surgery. These techniques are associated with higher pregnancy rates, improved sperm parameters and lower complication risks. However patient selection and surgical technique are crucial factors for optimal outcomes (Kirby *et al*., 2016; Wang *et al*., 2015).

Table 2: Forest Plot Of Selected Studies Indicating Non-Surgical Management Outcomes

Studies	Odd Ratio	Upper Confidence Level	Lower Confidence Level
(Pyrgidis et al., 2021)	2.28	12.09	6.41
(Agarwal et al., 2023)	2.97	4.63	1.19
(Arhin et al., 2021)	90.21	13.69	6.6
(Ghanem et al., 2010)	3.76	13.64	1.03
(Busetto et al., 2024)	2	4.14	0.97

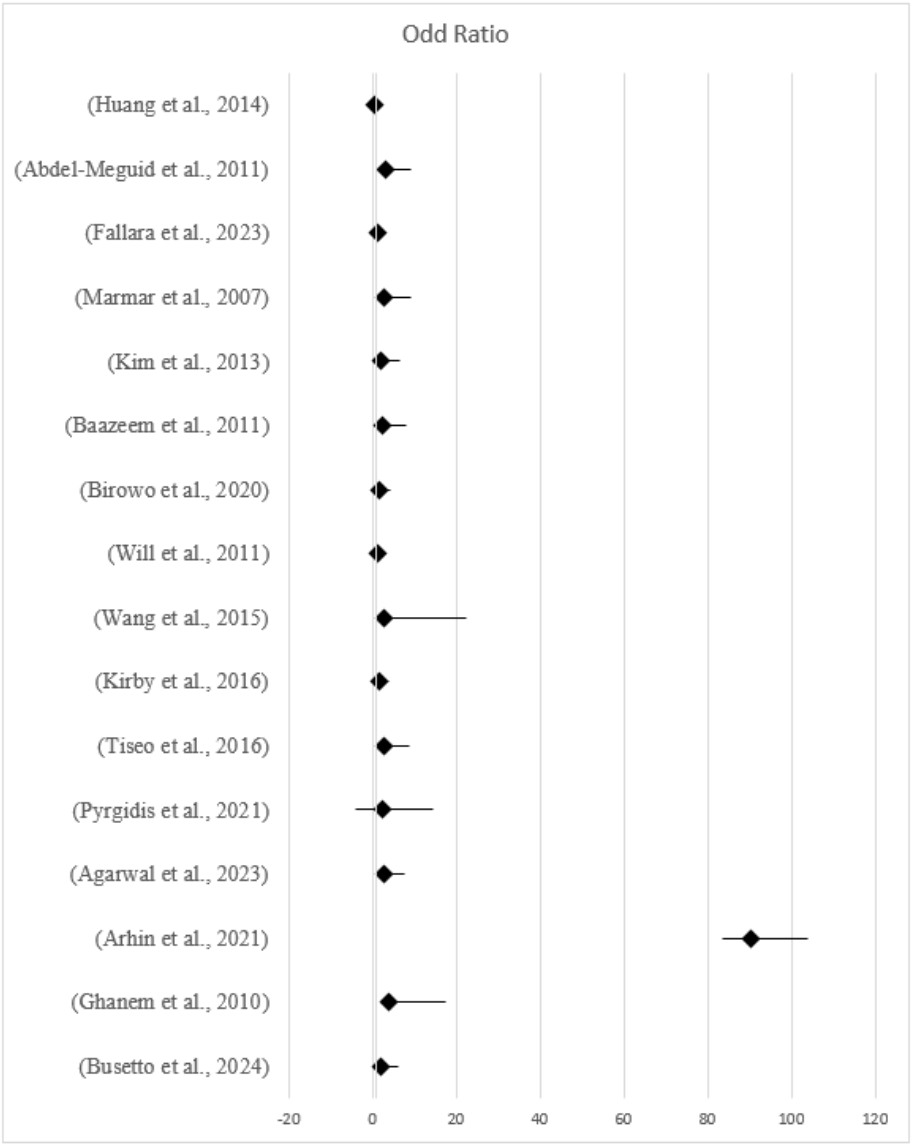


Analysis of Non-Surgical Management to Compare Improved Fertility Outcomes

The analysis of the studies regarding non-surgical management of varicocele for improving fertility outcomes highlights several findings. (Pyrgidis *et al*., 2021) suggest that antioxidant supplementation does not significantly improve pregnancy rates or semen parameters in patients with varicocele associated infertility, unless previous screening for oxidative stress was conducted.

Table 3: Comparative Evaluation Of Surgical And Non-Surgical Management Of Varicocele To Express Fertility Outcomes- Pooled Studies

Studies	Odd Ratio	Lower Confidence level	Upper confidence Level
(Huang et al., 2014)	0.7	0.92	0.76
(Abdel-Meguid et al., 2011)	3.04	5.98	1.84
(Fallara et al., 2023)	1.29	1.65	1
(Marmar et al., 2007)	2.87	6.2	1.33
(Kim et al., 2013)	1.9	4.66	0.77
(Baazeem et al., 2011)	2.23	5.78	0.86
(Birowo et al., 2020)	1.82	2.41	1.37
(Will et al., 2011)	1.1	1.68	0.73
(Wang et al., 2015)	2.9	19.6	1.92
(Kirby et al., 2016)	1.76	2.284	1.267
(Tiseo et al., 2016)	2.87	6.02	1.33
(Pyrgidis et al., 2021)	2.28	12.09	6.41
(Agarwal et al., 2023)	2.97	4.63	1.19
(Arhin et al., 2021)	90.21	13.69	6.6
(Ghanem et al., 2010)	3.76	13.64	1.03
(Busetto et al., 2024)	2	4.14	0.97



While (Agarwal *et al.*, 2023) acknowledged that the efficacy of antioxidant treatments in improving pregnancy rates, although the evidence quality was noted to be low. (Arhin *et al.*, 2021) stated that some antioxidant treatment including L-carnitine + Acetyl-carnitine may improve sperm outcomes in sub fertile patients, combinations with other antioxidants were not effective. This suggests variability in the effectiveness of different antioxidant combinations.

Ghanem's randomized controlled trial provided results for a combination treatment of Clomiphene sitrate and vitamin E, showing a significant higher pregnancy rate and improved sperm parameters in cases of idiopathic oligoasthenoozospermia (Ghanem *et al.*, 2010).

(Busetto *et al.*, 2024) indicates a statistically significant increase in sperm concentration with antioxidant treatment compared to placebo, supporting the potential benefits of antioxidants in improving fertility outcomes. However, younger age and lower BMI are associated with positive outcomes, while varicocele itself does not significantly impact sperm concentration values.

Comparative Evaluation of Surgical and Non-Surgical Approaches in Managing Varicocele for Enhanced Fertility Outcomes –Pooled Studies

Studies comparing surgical and non-surgical management of varicocele have shown that surgical treatment significantly improves pregnancy rates, sperm parameters, live birth rates, and success of sperm retrieval. It also offers long-lasting improvements in semen quality, particularly in men with azoospermia.

Non-surgical treatment, such as varicocele embolization, offers faster recovery, minimal invasiveness, and immediate pain relief. It is performed under local anesthesia, reducing risks and costs associated with surgery. It also offers effective pain relief and a lower recurrence rate compared to surgery.

Antioxidant supplementation alone does not significantly improve pregnancy rates or semen parameters in varicocele-associated infertility. However, some studies suggest combining antioxidants with other treatments like clomiphene citrate and vitamin E, leading to improved pregnancy rates and sperm parameters in specific cases.

According to guidelines from the European Association of Urology (EAU) and the American Society for Reproductive Medicine (ASRM), varicocele correction, including surgical and angiographic embolization, is beneficial for lowering sperm DNA fragmentation (SDF) and increasing reproductive results (Busetto *et al.*, 2022; Garg & Kumar, 2016).

Conclusively, surgical intervention such as Varicoceleectomy continues to be the principal means of enhancing the quality of life for sperm parameters, long-term outcomes, and pregnancy rates in men with varicocele. Varicocele embolization is one of the non-surgical methods that offers less invasiveness and a quicker rate of recovery.

Discussion

Varicocele, a prevalent condition affecting men, especially those with infertility, is caused by venous reflux and elevated hydrostatic pressure, with its impact on fertility outcomes being a significant concern.

Varicoceleectomy, a surgical procedure, restricts veins to redirect blood flow, while non-surgical techniques like Varicocele embolization offer reduced complications and faster recovery, requiring comparison to understand their effectiveness in managing problems and improving reproductive outcomes.

The study used a systematic approach to identify studies comparing surgical and non-surgical varicocele management, focusing on fertility rate improvements, effectiveness, randomized controlled trials, and complete English texts.

The meta-analysis screened randomized controlled trials and cohort studies involving adult male patients with varicocele, evaluating management strategies. Forest plots were used to visually summarize findings, while a modified QUADAS questionnaire was used for risk of bias assessment. This critical evaluation minimized bias and enhanced the reliability of the results.

Surgical Varicocele treatment, such as Varicoceleectomy, has been shown to significantly improve fertility outcomes in men with varicocele and abnormal semen parameters. Studies have shown improved pregnancy rates, sperm concentration, motility, and morphology in couples where the male partner undergoes varicocele repair (Persad *et al.*, 2021). This improvement is observed in men with severe conditions like azoospermia and has a high success rate of surgical retrieval for use in IVF (Zengerling, 2022).

Microsurgical Varicoceleectomy offers a long-lasting solution, showing sustained improvement in semen parameters for up to 12 months' post-surgery. However, the most significant benefits were seen in men with clinically detectable varicocele and abnormal semen analysis. Preoperative factors such as age and baseline sperm density can influence the success of Varicoceleectomy (Phan *et al.*, 2021). Microsurgical approaches like inguinal or sub inguinal may offer advantages over traditional open surgery, but patient selection and surgical technique are crucial factors for optimal outcomes.

Non-surgical management of varicocele for improving fertility outcomes has also been studied. Studies suggest that antioxidant supplementation does not significantly improve pregnancy rates or semen parameters in patients with varicocele-associated infertility, unless previous screening for oxidative stress was conducted (Pyrgidis *et al.*, 2021). Non-surgical treatments like varicocele embolization offer faster recovery, minimal invasiveness, and immediate pain relief. Antioxidant supplementation alone does not significantly improve pregnancy rates or semen parameters in varicocele-associated infertility (Inci & Gunay, 2013). Some studies suggest combining antioxidants with other treatments, leading to improved pregnancy rates and sperm parameters in specific cases.

Limitations

- The evaluation of long-term advantages may be hampered by the lack of long-term data on reproductive outcomes following treatment, especially for non-surgical methods.
- The inclusion of studies with varying designs, patient populations, and outcome measures resulted in heterogeneity and impact the applicability of the findings.
- The publication bias, where positive results are more likely to be published, can potentially affect the overall effect estimates and interpretation of findings.
- The reliability and validity of the meta-analysis results may be affected by variability in the quality of included studies, despite using a modified QUADAS questionnaire for risk assessment.

CONCLUSION

In conclusion, surgical treatment like Varicoceleectomy remains a primary option for improving fertility outcomes in men with varicocele, offering significant benefits in terms of pregnancy rates, sperm parameters, and long-term results. Non-surgical approaches like varicocele embolization provide alternatives with faster recovery and minimal invasiveness, while antioxidant supplementation may have a supportive role in combination therapies but does not show conclusive benefits as a standalone treatment.

Recommendations

- Increase the number of RCTs comparing surgical and non-surgical varicocele management, particularly with long-term follow-ups, to evaluate sustained fertility outcomes.
- Conduct subgroup analyses based on preoperative factors like age, baseline sperm parameters, and varicocele severity can identify patient groups that benefit most from different management approaches.
- Longitudinal studies should be encouraged to assess the long-term impact of non-surgical techniques like varicocele embolization beyond the immediate post-treatment period.
- The study suggests incorporating cost-effectiveness analyses to evaluate the economic impact of various varicocele management strategies, considering both short-term and long-term costs.

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