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SYSTEMATIC REVIEW

A systematic review and meta-analysis on the efficacy of internal spermatic artery ligation during laparoscopic varicocelectomy in children and adolescents: Is it safe?

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Summary *Introduction: Challenges in identifying small testicular arteries and lack of microscopic experience have led to a rising trend in the use of laparoscopic technique for pediatric and adolescent varicocele. The controversy over artery ligation (AL) and artery preservation (AP) during laparoscopic varicocelectomy (LV) is still debatable. This study investigates the effectiveness of AL and AP during LV in pediatric and adolescent varicocele cases.*

Methods: The systematic searches based on PRISMA guideline were conducted in PubMed, Scopus, ScienceDirect, Web of Science and ProQuest databases with pre-defined keywords. Both quantitative and qualitative analyses were performed to assess catch-up growth, persistence, recurrence, hydrocele, operative time, post-operative testicular volume, and sperm analysis.

Results: A total of 1512 patients from 9 eligible studies were included. There were no significant differences in catch up growth (OR 0.89; 95%CI 0.53, 1.51; p = 0.68) or hydrocele incidence (OR 0.59; 95%CI 0.28, 1.24; p = 0.16). The recurrence rate and persistence rate in AP group is significantly higher compared to AL group (OR 2.95; 95%CI 1.53, 5.68; p = 0.001 and OR 5.13; 95% CI 2.04, 12.88; p = 0.0005, respectively). The mean operative time during laparoscopic varicocelectomy is significantly longer when arteries are preserved as opposed to when they are ligated (OR 5.33; 95%CI 2.05, 8.60; p = 0.001). AL and AP both improved testicular volume and post-operative sperm analysis.

Conclusions: AL showed higher efficacy and comparable safety to AP. We recommend using AL with lymphatic sparing to minimize hydrocele complications.

KEY WORDS: *Adolescent; Pediatric andrology; Varicocele; Undescended; Testes; Laparoscopic; Ligation; Testicular artery.*

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INTRODUCTION

Varicocele is a medical condition characterized by the enlargement of the pampiniform plexus veins within the spermatic cord and is known to be a leading cause of male infertility (1, 2). The incidence in boys until puberty ranges from 2% to 11% and increases up to 16% in post-pubertal adolescents (3, 4). Inadequate management of varicocele in adolescents can lead to impairment of testicular growth, which can result in spermatogenesis dysfunction and infertility. Discomfort due to varicocele, testicular size asymmetry exceeding 20% or testicular atrophy, bilateral varicocele, and high-grade varicocele are indications of varicocelectomy in adolescents (5, 6). Previous studies have shown that testicular hypotrophy can improve in 40-100% of cases after varicocelectomy, significantly enhancing parameters such as sperm concentration, total and progressive motility, and morphology (7, 8).

Microsurgical varicocelectomy is still rarely used in the pediatric population due to several factors (9). Lack of experience with microscopic techniques, smaller testicular arteries, and lower blood pressure from systemic arteries in pediatric patients are difficulties that make arterial identification more difficult in the subinguinal or inguinal approach. Consequently, there has been a growing adoption of laparoscopic techniques by pediatric urologists over the past decade. This is primarily attributed to the numerous advantages these techniques offer, including faster operating and recovery times as well as visualization capabilities comparable to microsurgery (10, 11). *Laparoscopic varicocelectomy* (LV) using Palomo's method, which involves the simultaneous ligation of the *internal spermatic vein* (ISV) and internal spermatic artery (ISA), has demonstrated a favorable success rate without any significant increase in the risk of testicular atrophy (12).

However, there is debate among pediatric urologists regarding the importance of artery preservation during varicocelectomy. The controversy surrounding the need for *artery preservation* (AP) during LV has also been reported in several studies. Some studies suggest that the AP procedure is more appropriate as it prevents iatrogenic testicular trauma and reduces the incidence of postoperative hydrocele, while others report that *artery ligation* (AL) has a low recurrence and hydrocele rate but may disrupt testicular growth and future fertility. Conversely, the AP procedure has been associated with higher rates of persistence and recurrence compared to AL during LV (3, 4, 13). Currently, there is a lack of well-established *evidence-based medicine* (EBM) studies comparing AL and AP during LV. In order to determine the impact of arterial ligation following LV, this systematic review and meta-analysis aims to assess the efficacy and safety of laparoscopic varicocelectomy, comparing procedures with or without artery preservation in pediatric and adolescent population.

Materials and methods

This study followed a predetermined protocol according to the guidelines outlined by the *Preferred Reporting Items for Systematic Reviews and Meta-analyses* (PRISMA) (14) Initial searches were conducted to ensure that the specific characteristics outlined in the PICO (*Population, Intervention, Comparison, Outcome*) framework had not been previously investigated, thereby avoiding duplication of existing meta-analyses. The literature searches were conducted using several databases, including *PubMed*, *Scopus*, *ScienceDirect*, *Web of Science*, and *ProQuest*. The selected keywords used for the search were described as "*varicocele*", "*varicocelectomy*", "*laparoscopic varicocelectomy*", "*laparoscopic Palomo*", "*ligated artery*", "*artery ligation*", "*spared artery*", "*artery sparing*", "*preserved artery*", and "*artery preservation*".
The study's protocol was registered with PROSPERO (CRD42023445437).

Criteria for inclusion and exclusion

To be considered for inclusion, eligible articles need to meet specific criteria. These criteria included comparative studies, written in English, having at least two comparison groups, and reporting data on catch-up growth, persistence, recurrence, hydrocele, and operation time in laparoscopic varicocelectomy with or without artery preservation. During the selection process, studies that fell under the following categories were excluded: animal experimental studies, publication types other than original research, unpublished articles, and abstract-only findings.

Quality assessment

The assessment of potential research bias in non-randomized studies was conducted using the *Newcastle-Ottawa Scale* (NOS), which evaluates parameters related to selection, comparability, and exposure. The results obtained from the NOS assessment are categorized into three groups. A score ranging from 0 to 3 implicates a low-quality study, a score from 4 to 6 implicates a medium-quality study, and a score from 7 to 9 implicates a high-quality study. For *randomized controlled trial* (RCT) studies, the assessment of potential research bias was conducted using the Cochrane RoB tools V2, which evaluates four domains, such as randomization process, deviations from intended intervention, missing outcome data, measurement, and selection of reported outcome (15).

Statistical analysis

The measured endpoints included catch-up growth, persistence, recurrence, hydrocele incidence, and mean operative time. For the dichotomous variable analysis, *Odds Ratio* (OR) with a 95% *Confidence Interval* (CI) was used, and a p-value below 0.05 was considered statistically significant. The continuous variable was assessed using *Mean Difference* (MD). Heterogeneity between studies was evaluated using I^2, where an I^2 value above 50% indicated high heterogeneity and a random-effects model was applied for pooled analysis. If I^2 was less than 50%, a fixed-effects model was used. The statistical analysis

Data extraction

Two separate researchers collected the data using a predefined extraction template. In cases of discrepancies or disagreements during data extraction, a third investigator would be involved to discuss and make the final decision. The extracted information encompassed various aspects, including study details (such as authors, publication date, study design, sample size, inclusion and exclusion criteria, and follow-up duration), subject characteristics at baseline (such as age, intervention types, and study location), also qualitative and quantitative outcomes (such as catch-up growth, persistence, recurrence, hydrocele, operation time, testicular volume, and sperm analysis).

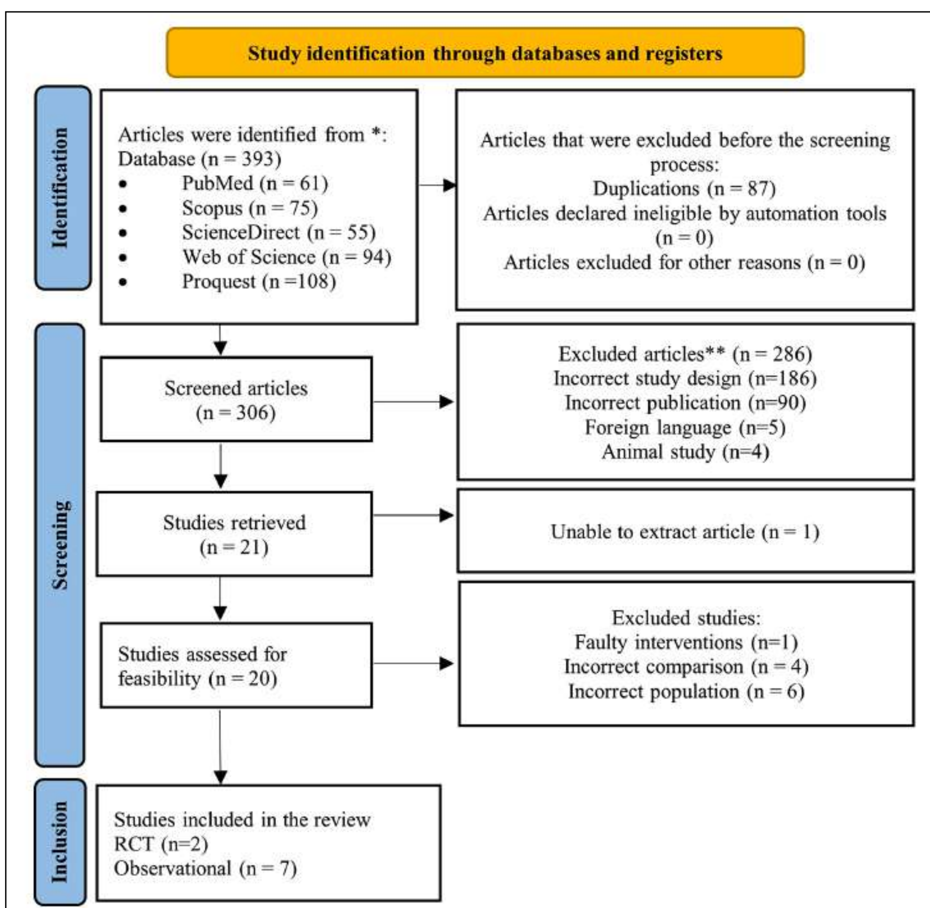


Figure 1.
identification of studies.

Table 1.
Characteristics data of included studies.

Study	Design	Age (years)	Intervention	Sample size	Varicocele type	Degree of varicocele	Outcome	Follow up (month)
Lund, 1999 (17)	Observational	12.9 (8-15)	Laparoscopy varicocelectomy	AP 13 AL 7	6 (left), 7 (bilateral)	NR NR	Recurrency, catch up growth	6-48
F. Varlet, 2000 (16)	Observational	12.15 (7-16)	Laparoscopy varicocelectomy	AP 28 AL 59	84 (left), 3 (bilateral)	NR NR	Persistency, testicular hypotrophy/ atrophy, catch up growth	11.1 (2-36)
Ciro Esposito, 2001 (6)	Observational	11.5 (6-17)	Laparoscopy varicocelectomy	AP 30 AL 181	209 (left), 2 (bilateral)	I: 26, II :98, 7 III: 8	Hydrocele, Recurrency	26 (12-72)
Nicola Zampieri, 2007 (20)	RCT	14.3 (12-16)	Laparoscopy varicocelectomy	AP 59 AL 63	59 (left) 63 (left)	II: 82, III: 40	Recurrency/persistency, Hydrocele, Operative time, Sperm quality parameters	18
A.M. Fast, 2013 (13)	Observational	15.5 (9.3-20.6)	Laparoscopy varicocelectomy or lymph node sparing laparoscopy varicocelectomy	AP 41 AL 312	28 (left), 13 (bilateral) 241 (left), 71 (bilateral)	NR NR	Recurrency, catch up growth	30.5 33.3
K.S. Kim, 2013 (19)	Observational	13.2 ± 2.1	Laparoscopy varicocelectomy	AP 50 AL 42	50 (left) 42 (left)	II: 10, III: 40 II: 9, III: 33	Recurrency/persistency, Catch up growth, Operative time	21 ± 12.3
Weimin Yu, 2015 (4)	Observational	17.3 ± 2.4	Laparoscopy varicocelectomy	AP 57 AL 65	122 (left)	II: 36, III: 21 II: 41, III: 24	Recurrency, Hydrocele, Catch up growth, Sperm quality parameters	17.1 ± 7.4 17.8 ± 7.0
Ciro Esposito, 2017 (8)	Observational	12.5 (8-17)	Laparoscopy varicocelectomy or lymph node sparing laparoscopy varicocelectomy	AP 10 AL 335	345 (left)	III: 10 II: 66, III: 269	Recurrency, operative time, testis volume, hydrocele	28.8 ± 8.3
Abdelaziz Yehya, *2020* (18)	RCT	14.25 ± 1.6	Lymph node sparing laparoscopy varicocelectomy	AP 80 AL 80	160 (left)	II: 28, III: 52 II: 32, III: 48	Persistency, Catch up growth, operative time, testicular volume	42

NR: Not Reported; AP: Artery Preservation; AL: Artery Ligation.

was conducted using RevMan 5.4 for Windows software, and the results were presented through Forest plots and descriptive narratives.

Results

Systematic search results

An initial 393 articles were found according to the used keywords. Complete eligibility assessment resulted in nine matched articles for further qualitative and quantitative analysis (Figure 1). Seven included studies were retrospective cohorts in design, while the other two were RCTs.

Baseline characteristics of the included studies

This research included a total of 1512 patients with a mean age of 13.7 years, ranging from 6 to 20 years old. These participants comprised various articles published between 1999 and 2020.

This study represented a total of 1409 patients with unilateral left-side varicocele and 103 patients with bilateral varicocele. Most of the participants presented with varicocele grade II-III. The detailed characteristics and outcomes data of the included studies are shown in Table 1 and Table 2.

Risk of bias assessment

Regarding the selection aspect, all included studies demonstrated a robust selection process, ensuring the populations were fairly representative of young men with varicocele. Moreover, the comparative and exposure aspects were well addressed, with adequate follow-up duration and relatively low dropout rates. Based on the final assessment, three studies achieved a NOS score of eight, while the other four studies received a NOS score of seven, indicating a low risk of bias (Table 3). However, the RCT studies assessed using the Cochrane RoB tool V2 (Figure 2) raised some concerns due to insufficient clarity regarding the randomization process described in the article.

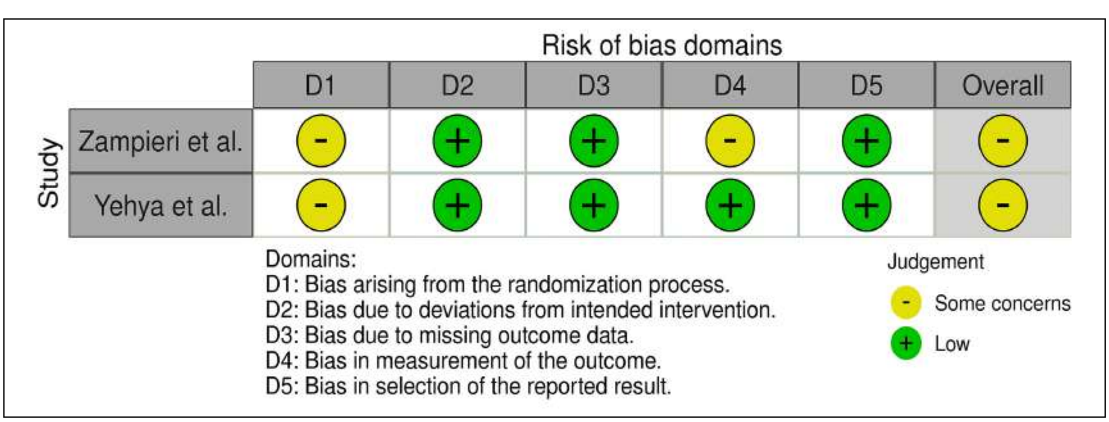


Figure 2.
Risk of bias assessment.

Table 2.
Outcomes data of included studies.

Study	Intervention	Recurrence	Persistence	Hydrocele	Catch-up growth 12 months	Catch-up growth 24 months	Catch-up growth Final visit	Post-op Hypotrophy/ Testicular Atrophy	Operative time (minutes)	Post-op Sperm Analysis Sperm count (miillion/ml)	Post-op Sperm Analysis Motility (%)	Post-op Sperm Analysis Morphology (%)	Volume testis Pre op	Volume testis Post op
Lund, 1999	AP	2/20	NR	3/20	NR	NR	18/20	NR	NR	NR	NR	NR	NR	NR
	AL	2/7	NR	0/7	NR	NR	5/7	NR	NR	NR	NR	NR	NR	NR
F. Varlet, 2000	AP	NR	9/28	11	NR	NR	3/12	1/12	NR	NR	NR	NR	NR	NR
	AL	NR	5/60		NR	NR	11/30	3/30	NR	NR	NR	NR	NR	NR
Ciro Esposito, 2001	AP	2/30	NR	0/30	NR	NR	NR	0/30	30 (20-70)	NR	NR	NR	NR	NR
	AL	3/181	NR	14/181	NR	NR	NR	0/181		NR	NR	NR	NR	NR
Nicola Zampieri, 2007	AP	5/59	1/59	1/59	NR	NR	NR	NR	35-60	73.81 (0.2-250)	45.73 (0-75)	45.13 (9-89)	NR	NR
	AL	0/63	0/63	8/63	NR	NR	NR	NR	20-40	58.85 (3.5-182)	39.04 (11-68)	38 (6-85)	NR	NR
A. M. Fast, 2013	AP	5/41	NR	NR	12/33	22/33	27/33	0/41	NR	NR	NR	NR	NR	NR
	AL	17/312	NR	NR	81/236	147/236	194/236	0/312	NR	NR	NR	NR	NR	NR
K.S. Kim, 2013	AP	8/50	3/50	0/50	14/15	NR	NR	0/50	83.1 ± 31.8	NR	NR	NR	NR	NR
	AL	1/42	1/42	2/42	9/10	NR	NR	0/42	72.5 ± 33.4	NR	NR	NR	NR	NR
Weimin Yu, 2015	AP	3/57	NR	4/57	14/23	18/23	NR	NR	41.3 ± 8.8	62.5 ± 39.2	52.2 ± 16.6	11.5 ± 1.5	NR	NR
	AL	2/65	NR	4/65	10/24	19/24	NR	NR	39.5 ± 7.1	60.4 ± 38.2	49.1 ± 19.9	10.7 ± 1.5	NR	NR
Ciro Esposito, 2017	AP	1/10	NR	2/10	NR	NR	NR	0/10	26 (18-50) 29.3 ± 10.3	NR	NR	NR	12.4 ± 4.9	NR
	AL	4/335	NR	23/335	NR	NR	NR	0/335	17 (14-45) 17.6 ± 5.3	NR	NR	NR	12.0 ± 5.2	15.4 ± 4.8
Abdelaziz Yehya, 2020	AP	NR	8/80	0/80	NR	68/80	NR	0/80	40 ± 2.6	NR	NR	NR	12.2 ± 3.1	16.3 ± 4
	AL	NR	1/80	0/80	NR	71/80	NR	0/80	35 ± 2.8	NR	NR	NR	14.1 ± 4.6	17.1 ± 5.1

NR: Not Reported; AP: Artery Preservation; AL: Artery Ligation.

Table 3.
Risk of bias assessmment using Newcastle Ottawa Scale.

Authors	Selection	Comparatibility	Exposure	Total Score
Lund, 1999	***	**	***	8
Varlet et al. 2000	***	**	***	8
Esposito et al. 2001	***	**	***	8
Kim et al. 2013	***	**	**	7
Fast et. al 2013	***	**	**	7
Weimin Yu et al. 2015	***	**	**	7
Esposito et al. 2018	***	**	**	7

Meta-analysis result on catch-up growth

Based on a meta-analysis of the six papers included (4, 13, 16-19), there is no statistically significant difference in the amount of catch-up growth between AL and AP during laparoscopic varicocelectomy (OR 0.89; 95%CI 0.53, 1.51; p = 0.68) (Figure 3). The fixed-effects model was used due to low heterogeneity between studies (p = 0.81; I^2 = 0%). Of the six studies, *Fast et al.* and *Yehya et al.* represented higher statistical weight compared to other studies due to a larger sample size (13, 18).

Meta-analysis result on persistence rate

Four studies were analyzed in this meta-analysis (16, 18-20), the persistence rate revealed a significant difference in which the AP group provided the higher persistence compared to the AL group (OR 5.13; 95%CI 2.04, 12.88; p = 0.0005) (Figure 4). Because of the low heterogeneity observed between studies, the fixed-effects model was employed (p = 0.88; I^2 = 0%).

Figure 3.
Meta-analysis result on catch-up growth.

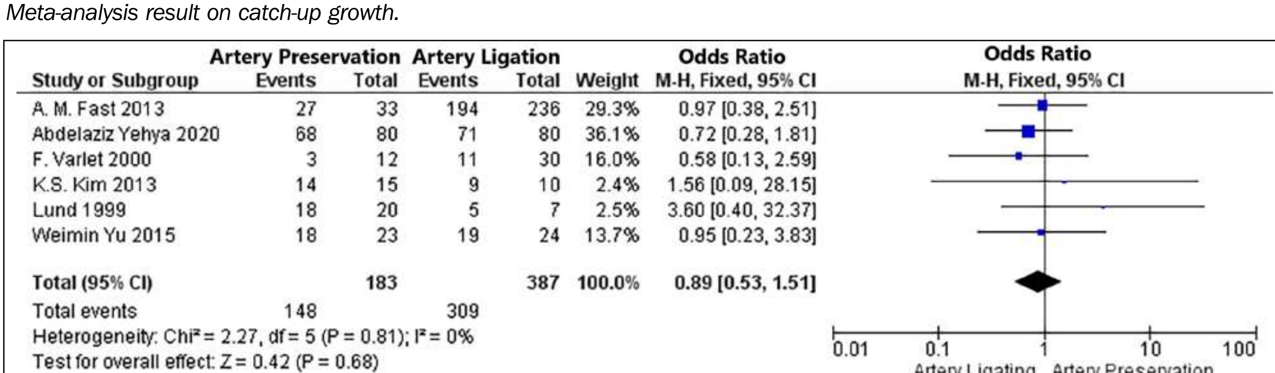


Figure 4.
Meta-analysis result on persistence rate.

Study or Subgroup	Artery Preservation Events	Artery Preservation Total	Artery Ligation Events	Artery Ligation Total	Weight	Odds ratio M-H, Fixed, 95% CI
Abdelaziz Yehya 2020	8	80	1	80	19.8%	8.78 [1.07, 71.91]
F. Varlet 2000	9	28	5	60	47.4%	5.21 [1.55, 17.50]
K.S. Kim 2013	3	50	1	42	22.4%	2.62 [0.26, 26.14]
Nicola Zampier 2007	1	59	0	63	10.4%	3.26 [0.13, 81.52]
Total (95% CI)		**217**		**245**	**100.0%**	**5.13 [2.04, 12.88]**
Total events	21		7			

Heterogeneity: Chi² = 0.66, df = 3 (P = 0.88); I² = 0%
Test for overall effect: Z = 3.48 (P = 0.0005)

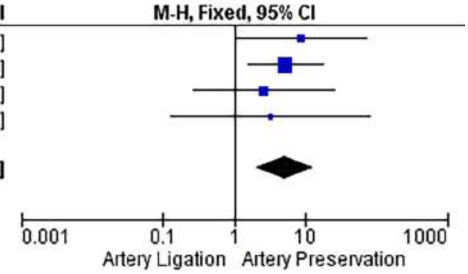


Figure 5.
Meta-analysis result on recurrence rate.

Study or Subgroup	Artery Preservation Events	Artery Preservation Total	Artery Ligation Events	Artery Ligation Total	Weight	Odds Ratio M-H, Fixed, 95% CI
A. M. Fast 2013	5	41	17	312	33.8%	2.41 [0.84, 6.92]
Ciro Esposito 2001	2	30	3	181	7.8%	4.24 [0.68, 26.50]
Ciro Esposito 2017	1	10	4	335	2.0%	9.19 [0.93, 90.72]
K.S. Kim 2013	8	50	1	42	8.9%	7.81 [0.93, 65.25]
Lund 1999	2	20	2	7	26.0%	0.28 [0.03, 2.50]
Nicola Zampier 2007	5	59	0	63	4.3%	12.82 [0.69, 237.06]
Weimin Yu 2015	3	57	2	65	17.3%	1.75 [0.28, 10.86]
Total (95% CI)		**267**		**1005**	**100.0%**	**2.95 [1.53, 5.68]**
Total events	26		29			

Heterogeneity: Chi² = 7.78, df = 6 (P = 0.25); I² = 23%
Test for overall effect: Z = 3.23 (P = 0.001)

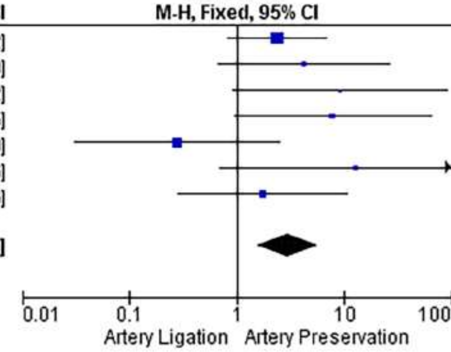
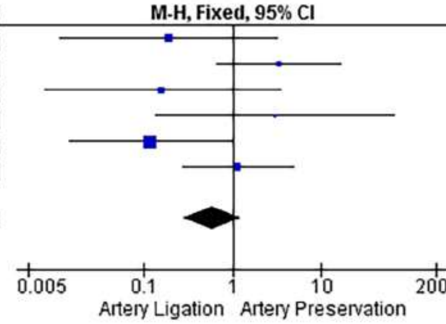


Figure 6.
Meta-analysis result on hydrocele incidence.

Study or Subgroup	Artery Preservation Events	Artery Preservation Total	Artery Ligation Events	Artery Ligation Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Ciro Esposito 2001	0	30	14	181	21.2%	0.19 [0.01, 3.26]
Ciro Esposito 2017	2	10	23	335	5.4%	3.39 [0.68, 16.90]
K.S. Kim 2013	0	50	2	42	13.7%	0.16 [0.01, 3.44]
Lund 1999	3	20	0	7	3.1%	3.00 [0.14, 65.55]
Nicola Zampier 2007	1	59	8	63	38.8%	0.12 [0.01, 0.98]
Weimin Yu 2015	4	57	4	65	17.7%	1.15 [0.27, 4.83]
Total (95% CI)		**226**		**693**	**100.0%**	**0.59 [0.28, 1.24]**
Total events	10		51			

Heterogeneity: Chi² = 9.99, df = 5 (P = 0.08); I² = 50%
Test for overall effect: Z = 1.39 (P = 0.16)



Meta-analysis result on recurrence rate

Seven studies were analyzed for this outcome (8, 13, 17-21). On pooling analysis of the data, the recurrence rate in AP group is higher compared to AL group (OR 2.95; 95%CI 1.53, 5.68; p = 0.001) (Figure 5). Most of the studies demonstrated a higher recurrence rate in artery preservation group, except for one study (17). The fixed-effects model was applied because there was minimal heterogeneity observed between studies (p = 0.25; I^2 = 23%).

Meta-analysis result on hydrocele incidence

The analysis of six included studies reveals that there is no significant statistical difference in hydrocele incidence between AL and AP during laparoscopic varicocelectomy (OR 0.59; 95%CI 0.28, 1.24; p = 0.16) (Figure 6) (4, 8, 17, 19-21). The choice of the fixed-effects model was based on the minimal heterogeneity observed among the studies (p = 0.08; I^2 = 50%). *Varlet et al*. reported 11 patients with postoperative hydrocele, but the number of patients in each group was unknown (16).

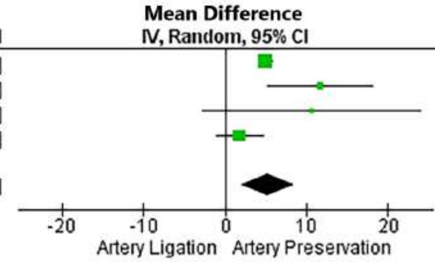
Meta-analysis result on mean operative time

According to a meta-analysis of the four papers included (8, 18-20), the mean operative time during laparoscopic varicocelectomy is significantly longer when arteries are preserved as opposed to when they are ligated (OR 5.33; 95%CI 2.05, 8.60; p = 0.001) (Figure 7). The mean operative time was expressed in minutes. Due to significant heterogeneity observed between studies, the random-effects model was employed (p = 0.02; I^2 = 69%). *Esposito*

Figure 7.
Meta-analysis result on mean operative time.

Study or Subgroup	Artery Preservation Mean	SD	Total	Artery Ligation Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Abdelaziz Yehya 2020	40	2.6	80	35	2.8	80	44.3%	5.00 [4.16, 5.84]
Ciro Esposito 2017	29.3	10.3	10	17.6	5.3	335	16.6%	11.70 [5.29, 18.11]
K.S. Kim 2013	83.1	31.8	50	72.5	33.4	42	5.3%	10.60 [-2.81, 24.01]
Weimin Yu 2015	41.3	8.8	57	39.5	7.1	65	33.8%	1.80 [-1.06, 4.66]
Total (95% CI)			**197**			**522**	**100.0%**	**5.33 [2.05, 8.60]**

Heterogeneity: Tau² = 6.13; Chi² = 9.57, df = 3 (P = 0.02); I² = 69%
Test for overall effect: Z = 3.19 (P = 0.001)



et al. reported an average operating time of 30 minutes. However, it was unclear for each group (6).

Qualitative synthesis of testicular volume
In this study, two separate studies reported the change in testicular volume before and after surgery (8, 18). There was an increase in testicular volume observed in both AL and AP groups during laparoscopic varicocelectomy. However, the significance of the difference could not be analyzed due to the absence of one data point in the post-surgery testicular volume in the study conducted by *Esposito et al.* (8).

Qualitative synthesis of postoperative sperm analysis
Two included studies provided information regarding post-surgery sperm analysis in the AL and AP groups (4, 20). The results reported that AL and AP laparoscopic varicocelectomy both resulted in normal sperm parameters following the surgery, with slightly higher values observed in the AP group. However, due to the lack of studies reporting sperm analysis after the surgery, it was not possible to analyze and provide the quantitative data comprehensively. However, the initial result of this qualitative analysis may provide an idea that there is no difference in postoperative sperm outcome between AP and AL during laparoscopic varicocelectomy.

Discussions

This is the first systematic review and meta-analysis that compares the efficacy and safety of AL and AP during LV in pediatric and adolescent population. In our research, we have prioritized catch-up growth as the main focus due to its significant potential for enhancing testicular function and positively influencing fertility outcomes in individuals with varicocele. Both AL and AP groups demonstrated an increase of 63 to 86% testicular catch-up growth within 12 to 24 months after surgery (22-25). *Weimin Yu et al.* in their study, reported that a lower rate of catch-up growth was observed in the AL group during the first year of follow-up. They suggested that the remodeling of neovascularization in testicular drainage after the AL procedure, which is important for maintaining normal testicular metabolism, may require a relatively longer time (4). The findings of similar outcome in catch-up growth between AL and AP procedures in this study may be due to the fact that both techniques demonstrated identical effects on testicular blood flow (26). As observed in a recent meta-analysis, surgical correction of varicocele may result in superior catch-up growth of the affected testis. It can be inferred that the acceleration of growth in the affected testes is attributed to the removal of the detrimental effects of varicocele on testicular development (19).

One of the concerns in this study was the incidence of postoperative hypotrophic testes. From the analysis of nine included studies, only study conducted by *Varlet et al.* reported the incident (4, 8, 13, 16-21). Contrast with *Yehya et al.*, whose study reported a significant increase in testicular volume even though the ISA were ligated during LV (18). Ligation above the level of the internal inguinal ring is considered safe because there are collateral arteries below the internal ring that play a role in providing an adequate blood supply to the testicle, preventing a significant decrease in oxygen and nutrient delivery (27, 28). Those collateral arteries become more favorable for maintaining blood supply to the testicles as a result of reduced blood flow from the main artery after ligation (8). Previous surgery on the inguinal area like hernia repair, may result in significant injury to the collateral testicular arteries, such as the cremasteric and differentialis arteries. These injuries may provide an impact on postoperative hypotrophy events in case AL procedure is performed (16). Although no studies have specifically observed the role of collateral arteries in testicular volume growth in the ligation artery group, an increase in volume suggests the occurrence of vascular adaptations. However, it is important to note that an increase in testicular volume after arterial ligation is not always accompanied by an increase in testicular function or sperm quality. Spermatogenesis may still be impaired due to loss of primary blood supply (20).

Sperm analysis after varicocelectomy in adolescents is not routinely examined because of the barriers of parental consent, even though it is an important parameter after varicocelectomy (29). This is maybe the reason that only two of our nine included studies reported the sperm analysis parameters post-operation (4, 20) According to the findings of *Zampieri et al.*, the AP group demonstrated superior semen quality compared to the AL group, even though there is no statistically significant difference between the two groups. In terms of mean sperm concentration outcome, the AP group demonstrated a higher value compared to the AL group (73.81 x 106 and 58.85 x 106, respectively). Furthermore, the AP group exhibited higher sperm motility (45.73%) compared to the AL group (39.04%), with a greater proportion of normal morphology sperm cells (45.13% *vs.* 38%). They believe that AP is necessary since preserving the normal blood supply of the arteries seems more appropriate to prevent testicular damage and dysfunction (20). Therefore, it is important to consider further studies with long-term follow-up to assess the parameters of sperm function and quality in the postoperative evaluation of the AL group before determining whether the AL method adversely affects testicular function and spermatogenesis.

Our study reveals a notable contrast in the recurrence and persistence rates between AP and AL groups. Specifically, the group that underwent arterial preservation showed a higher recurrence and persistence rate. This finding aligns with *Kattan et al.'s* findings, which reported that AP exhibited a higher recurrence rate compared to AL. This was mainly due to the presence of blood flow in non-functional collateral veins as a result of venous pressure increases following ISV ligation or failing to ligate the small veins along the anterior wall of ISA due to fear of injuring the artery. Mass ligation of the gonadal vessels allows for complete obliteration, thus preventing missed collateral veins (30). Another possible reason for persistency could be the existence of collateral veins that originate from the internal spermatic vein below the occlusion site and directly drain into the internal iliac vein or the inferior cava (31). However, there have been several studies reporting a low recurrent rate (0.6-3%), even though the testicular artery and lymphatic vessels are preserved. A study by *Chung et al.* declares that the possibility of missing small periarterial veins can be minimized. They can be easily divided and dissected using 3 mm mini laparoscopic instruments (32). However, future research needs to be done on a larger scale to prove this statement.

Our investigation showed no significant difference in the incidence of hydroceles between artery preservation and ligation, in contrast to the findings of a study by *Zampieri et al.*, which found a correlation between AL and the development of hydroceles. They suggest that the complete ligation of spermatic and lymphatic vessels can cause blood stasis within the scrotum (20). The risk of developing hydrocele may be increased if lymphatic preservation is not performed. However, there was no association between artery preservation or ligation and hydrocele incidence, as reported in a study by *Weimin Yu et al.* (4). *Liang et al.'s* meta-analysis indicated that selecting a lymphatic preservation method is advisable to decrease the occurrence of hydroceles. This is because the standard Palomo procedure does not involve the preservation of lymphatic glands, leading to the accumulation of lymphatic fluid in the scrotum, which contributes to a higher risk of hydrocele formation (33). *Mathias et al.* found that there was no significant difference between arterial sparring and ligation regarding the incidence of postoperative hydrocele in lymphatic sparing varicocelectomy. *Yehya et al.* also confirmed this by reporting no incidence of hydrocele in both the AP and AL groups during lymphatic sparring LV (18).

While we found that the AP group significantly had a longer mean operative time than the AL group, *Weimin Yu et al.* found no statistically significant difference between the two groups (4). The operating time may vary depending on the surgeon's experience (24). This is probably the reason that this outcome in this study possessed a higher heterogeneity compared to another outcome. This meticulous process involves carefully locating and preserving the arterial blood supply while removing or ligating the dilated veins causing the varicocele. The surgeon must exercise caution and take the necessary time to ensure the arteries are properly identified and spared from damage. Consequently, this longer time requirement is attributed to the surgeon's focus on accuracy and the intricate nature of preserving the arterial blood flow during the procedure (34). Together with practical experience, it appears that there is a learning curve that enables surgeons to perform this technique more efficiently, resulting in shorter operative times as their expertise grows (24).

One of several limitations of this meta-analysis is the lack of RCT studies in contrast with more observational studies. RCTs are considered the gold standard for establishing causal relationships due to their rigorous design and randomization process. On the other hand, observational studies rely on naturally occurring data and a lack of random assignment of participants, making them more susceptible to confounding factors and biases. Moreover, the long-term assessment regarding catch-up growth and testicular function following varicocelectomy in this age group could be feasibly obtained by performing prospective cohort studies and retrospective analyses. Several variations such as interventions in LV procedures where some were accompanied by lymphatic sparring and subsequently testicular development which were assessed by different standards became another limitation in this study. Therefore, outcome measures such as hydrocele and catch-up growth can be biased. We expect that future research will include longterm follow-up and a uniform examination of sperm parameters while adhering to strict ethical approval protocols.

Conclusions

This study highlights the superior efficacy of the AL technique, which maintains similar safety to the AP technique. We recommend adopting the AL technique with lymphatic sparing routinely to enhance efficacy and minimize hydrocele complications. Additionally, the evaluation of sperm parameters is essential to fully establish the efficacy profile of laparoscopic varicocelectomy in the pediatric and adolescent population.

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