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Review of current varicocelectomy techniques and their outcomes

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OBJECTIVES

- To review all the various techniques and their results and efficiencies to provide practicing urologists with some guidance for choice of technique
- To discuss improvements of varicocelectomy techniques in the last 15 years and their impact on results of surgery.

PATIENTS AND METHODS

- A PubMed English literature review of literature from 1995 to present.

RESULTS

- Pregnancy rates were highest with microsurgical subinguinal technique
- Varicocele recurrence rates were lowest with microsurgical subinguinal technique
- Hydrocele formation rates were lowest with microsurgical inguinal technique
- Surgical complications were highest in the laparoscopic technique
- Varicocelectomy by itself or in conjunction with IVF is cost effective

CONCLUSIONS

- Microsurgical subinguinal or microsurgical inguinal techniques offer best outcomes
- Varicocelectomy is a cost effective treatment modality for infertility
- Further research is needed to explore new developments in varicocelectomy

What's known on the subject? and What does the study add?
The relationship between varicocele and infertility is well established, and several surgical and radiological techniques for varicocelectomy are currently used in practice. The postoperative benefits of the surgery is also well established. The AUA has set forth guidelines on the evaluation and indications for treatment of varicocele; however, to date, there is no consensus as to which surgical technique should be considered the gold standard.

This paper evaluates the current methods in practice and evaluates them based on specific and stringent criteria. All surgical and radiological methods that are frequently used were included. We suggest that by using either of the two microsurgical techniques, inguinal or subinguinal, that there would be better outcomes across all parameters postoperatively with better long term outcomes. We also investigated several new techniques and made recommendations for further research.

KEYWORDS

varicocele, varicocelectomy, technique(s), infertility, outcome(s)

INTRODUCTION

Male infertility is a growing concern in developed countries around the world. The most common cause of male infertility is varicocele [1], a surgically correctable or at least improvable form of infertility. The causes of varicocele are multifactorial, but the end result is a pathological dilation of the veins draining the testicles, leading to increased temperature in the seminiferous tubules and decreased sperm quality [2]. Nagler *et al.* [3] estimated that over 13.4% of the general population and 37% of infertile men will be diagnosed with varicocele. A dramatic improvement can be seen after treating varicoceles, especially in conjunction with other infertility treatment methods. The pregnancy rate in patients who have undergone varicocelectomy increases substantially from 14% with no treatment to 29.7% after varicocelectomy, and up to 72% with varicocelectomy and *in vitro* fertilization (IVF) in a 2-year period [4].

A number of techniques for varicocelectomy are practised worldwide, including open surgical and laparoscopic techniques and the use of interventional radiology [5]. Each of these approaches has multiple sub-techniques and innovations, which can theoretically increase fertility and decrease complications. These techniques have been well described in the literature, and recommendations for diagnosis and indications for treatment have also been published [6], but to date there has been no consensus on which technique should be considered to be the 'gold standard'.

Conflicting reports from numerous articles published on efficacy and complications seen with individual techniques led us to believe there is a need to compare and contrast thoroughly the outcomes of existing techniques to provide better guidance for urologists when choosing their surgical approach. We sought to answer the

following question: which varicocelectomy technique has been shown to be of greatest benefit for the patient in terms of increased fertility, decreased postoperative complications and recovery time? We also reviewed the cost effectiveness of varicocelectomy compared with other infertility treatments. Here we report our comprehensive review findings.

SEARCH METHOD, KEYWORDS AND INCLUSION CRITERIA

A qualitative literary review was conducted using PubMed (http://www.ncbi.nlm.nih.gov/pubmed/), a search engine of the United States National Library of Medicine and the National Institutes of Health, and the MEDLINE database. We also searched individual urology journals and focused on publications from 2005 to the present. Newly developed, unpublished techniques were not included in our research because results for these are unverified.

The keywords that we searched on included: varicocele, varicocelectomy, technique(s), infertility, and outcome(s). The inclusion criteria were stringent to give priority to publications that identified widely used or new techniques, with enough data to be statistically significant. In all, 105 publications were found when the keywords 'varicocele/varicocelectomy, technique/techniques' were queried and 86 publications were presented when research published before 1995 was eliminated. We only included studies that offered pertinent data on spermatogenesis, pregnancy rates or cost effectiveness in order to focus on fertility factors. The present review includes 33 manuscripts from this search that fitted the following inclusion criteria: (i) original study or review article; (ii) published from January 1995 to June 2010; (iii) manuscript published in English, or an English translation available; (iv) sample size >30 patients; (v) author conformed to the AUA definition of the disease. Two of the 33 papers were review articles and original manuscripts cited therein were located and referenced, or data was extrapolated directly from these review publications and an annotation denoting the source was included. The inclusion criteria were applied to the manuscripts cited in the review articles as well, and only studies that fitted the inclusion criteria were evaluated and extrapolated.

RESULTS

Over 5000 patients pooled from 33 studies were evaluated in this review (Table 1 [4,7–33]) and, by using simple addition and division, we calculated the overall pregnancy rate to be 38.37% (954/2486). In addition to pregnancy rate we evaluated hydrocele formation and recurrence of varicocele (Table 2 [20]). The majority of authors did not differentiate between recurrence and persistence, i.e. did not differentiate between patients who developed more varicoceles after the original ones were removed, and patients who still had varicoceles immediately after the operation. The exception to this was the radiological embolization group, which has an approximate failure rate of 12% [11]; authors did report this failure. In the present study we found a 9.97% failure rate with the embolizing techniques. The formation of hydrocele was seen in all the approaches except the radiological ones because testicular lymphatics are not damaged during a radiological embolization. Other surgical complications were dependent on technique (Table 1), and ranged from transient pneumoscrotum in several laparoscopic approaches, to loss of a testicle attributable to technical surgical failure with an inguinal approach [11].

Seminal variables were reported in the majority of papers analysed. Authors reported sperm count, sperm motility and/or abnormal forms. It should be taken into consideration when evaluating the preoperative to postoperative data shown in the review table (Table 1) that not all patients will respond well to treatment, and between 20–37% will not respond at all. In 1996 Milad *et al.* [9] reported that 63% of patients had improved sperm count and 66% showed increased sperm motility after laparoscopic surgery. In 2000 Bebars [14] compared two techniques and found that seminal values improved by 43% and 51% using the Palomo and laparoscopic techniques, respectively. Using the microsurgical subinguinal technique in 2001, both Testini *et al.* [16], and Perimenis *et al.* [34] reported improved semen quality after surgery in 80% and 83.2% of patients, respectively. In 2002, Cayan *et al.* [17] reported that only 271/540 (50.2%) of patients had an increase of >50% in total motile sperm count. In 2009 Zampieri *et al.* [32] showed that 40.6% of laparoscopically treated patients and 58.3% of microsurgically treated patients had normalization of semen quality. In 2010 Smit *et al.* [35] used sperm DNA fragmentation calculated by the DNA fragmentation index as a measure of response to varicocelectomy. Patients were sub-divided into two groups: 'responders' had >50% increase in sperm concentration after surgery, and 'non-responders' did not reach the 50% mark. They showed that there was a significant decrease in sperm chromatin fragmentation ($P = 0.009$) in responders but not in non-responders ($P = 0.602$). Patients who responded had lower levels of apoptosis in postoperative biopsies compared with non-responders.

Few authors reported preoperative and postoperative hormonal levels or testicular size measurements, but hormonal data was reported by Cayan *et al.* (1999 [12]), Grober *et al.* [21] and Cayan *et al.* (2005 [24]) (Table 3). The 1999 Cayan *et al.* [12] study also reported free testosterone (ng/mL), which increased from 23.1 ± 3.19 to 32.8 ± 4.37 after surgery. Grober's study [21] was aimed at treating recurrent/persistent varicoceles, which proved to have similar trends/benefits as first attempts. Testicular size was evaluated by three authors (Table 4 [21,26,32]). Zampieri *et al.* [32] also reported 99/124 patients (79.8%) had statistically significant catch-up growth ($P < 0.05$) at 18 months after surgery, and that only 34/99 (34.3%) of patients with catch-up growth had equal bilateral testicular volumes and the other 65 were still mildly hypotrophied.

COST-EFFICACY

In 1997 Schlegel [10] estimated that the average cost of a live delivery after varicocelecomy was $26 268 (95% CI $19 138 to $44 656), and the average cost of a live delivery after intracytoplasmic sperm injection (ICSI) was $89 091 (95% CI $78 720 to $99 462). In 2002 Penson *et al.* [4] looked at the average cost in addition to the cost per live delivery in four groups (average cost, cost per live delivery): (i) observational: $1996, $13 863; (ii) varicocelectomy with IVF: $31 171, $44 522; (iii) intrauterine insemination (IUI) with IVF: $36 322, $49 757; (iv) immediate IVF: $39 001, $64 422. In 2006 Al-Hunayan *et al.* [25] showed that the laparoscopic technique could be carried out with two trochars instead of three, reducing the cost of the procedure. Another study in 2007 by Al-Kandari *et al.* [28] evaluated the cost of unilateral vs. bilateral

TABLE 1 Review of the varicocelectomy techniques used in the 33 studies evaluated

Author/Year	Total no. patients in study, *n* (No. patients in analysis when available)	Technique(s) used and compared	Patients in each sub-group, *n* (% resolved, if available) Patients with recurrence, *n* (%)	Formation of h ydrocele, *n* (%)	Outcome measured: (1) Spermatogenesis (2) Pregnancy rate (3) Hormone levels: testosterone, FSH, etc (4) Testicular volume and growth (vis-à-vis catch-up growth)	Other: (1) Complications (2) Cost-efficacy (3) Anaesthesia (4) Recovery time
Tan *et al.* 1995 [7]	107 (61)	Laparoscopic technique: description and results	107 (100%) N/A	N/A	(1) Average sperm count increased from 19×10^6/mL to 33.8×10^6/mL, average sperm motility increased from 33.1 to 39.1%, Percentage of abnormal sperm decreased from 69.9 to 45.9% ($P < 0.05$) (2) 8/61 (13.1% of patients) pregnancies reported within 1 year of surgery (3 & 4) N/A	(1) Pneumoscrotum in two patients (1.8%); Minor wound infection in two patients (1.8%); Post-extubation bronchospasm in two patients (1.8%); retention of urine in one patient (0.9%) (2) N/A (3) General anaesthesia (4) Outpatient procedure
Ferguson *et al.* 1995 [8]	87 (87)	Percutaneous embolization: description and results	79 (91%) N/A	N/A	(1) Sperm motility increased from 35% to 46% ($P < 0.001$), sperm improved, but $P < 0.1$. No significant change in volume or morphology (2) 29/87 (33%) of patients were able to achieve pregnancy. 3 & 4) N/A	N/A
Milad *et al.* 1996 [9]	32 (32)	Laparoscopic technique: description and results	32 N/A	3/32 (9.4%)	(1) Of the patients being treated for infertility, 63% had improved sperm count, and 66% showed increased sperm motility. (2) 5/32 (16%) of patients were able to achieve pregnancy 3 & 4) N/A	(1) 1/32 (3.1%) of patients had severe scrotal pain. 2–4) N/A
Schlegel 1997 [10]	N/A	Evaluated cost-effectiveness of varicocelectomy and pregnancy	N/A N/A	N/A	N/A	(1) N/A (2) The average cost of a live delivery after varicocelecomy was $26 268.00 (95% CI $19 138 to $44 656). The average cost of a live delivery after ICSI was $89 091.00 (95% CI $78 720 to $99 462). (3) N/A (4) Estimated 3 days postoperative recovery.

TABLE 1 Continued

Author/Year	Total no. patients in study, *n* (No. patients in analysis when available)	Technique(s) used and compared	Patients in each sub-group, *n* (% resolved, if available) Patients with recurrence, *n* (%)	Formation of h ydrocele, *n* (%)	Outcome measured: (1) Spermatogenesis (2) Pregnancy rate (3) Hormone levels: testosterone, FSH, etc (4) Testicular volume and growth (vis-à-vis catch-up growth)	Other: (1) Complications (2) Cost-efficacy (3) Anaesthesia (4) Recovery time
Shlansky-Goldberg *et al.* 1997 [11]	346	Compared inguinal/ Ivanissevich (I) and percutaneous embolization (E)	I: 149 (with 1% failure) E: 197 (with 12% failure) I: N/A (16%) E: N/A (4%)	N/A	(1) Although both procedures improved seminal quality, there was no statistical difference between the two groups for sperm density, percent increase in total sperm count, motility, and progression. The data showed the following increases in seminal values (data represented as % increased): Density: E-156.8% vs. I-138.5%; Total sperm count E-168.8% vs. I-157.9%; and motility: E-2.7% vs. I-3.2%. The percent of individuals who had a change in sperm progression was E-31% vs. I-41%. (2) I: 50/149 (34%) and E: 77/197 (39%) of patients were able to achieve pregnancy. No statistical difference in pre-procedure sperm count and % able to achieve pregnancy (compare with Nabi 2004). (3 & 4) N/A	(1) Minor complications for I: Wound infections and haematomas. Minor complication rate was 7%. Major complications for I: loss of patient's testicle, and incisional hernia. Minor complications for embolization: extravasation of contrast material, minor contrast material reactions, severe venous spasm, haematomas, or nontarget embolizations. Minor complication rate was 11%. Major complication for embolization was an arrhythmia thought to be related to sedation. (2) N/A (3) I: General anaesthesia. E: conscious sedation with midazolam hydrochloride and fentanyl citrate. 10 mg of nifedipine was given to reduce potential venous spasm in the gonadal vein (4) N/A
Cayan *et al.* 1999 [12]	78	Microsurgical inguinal technique in two groups of patients: Group1 – FSH <10 mIU/mL Group2 – FSH >10 mIU/mL	Group 1: 42 Group 2: 36 N/A	N/A	(1) Group 1 (before to after surgery): Sperm count (mil/mL) 28.8 ± 4.83 to 29.2 ± 4.92; motility (%) 27.5 ± 4.53 to 39.5 ± 4.53; Group 2: Sperm count 17.7 ± 4.35 to 30.9 ± 4.40; motility 20.8 ± 4.37 to 37.5 ± 4.34. (2) N/A (3) Group 1: FSH (before to after surgery): 7.37 ± 1.74 to 6.58 ± 1.54; Group 2: FSH (before to after surgery): 24.0 ± 3.3 to 15.1 ± 3.24 Testosterone (ng/mL) average for groups 1 and 2 (before to after surgery): 5.63 ± 1.4 to 8.37 ± 8.37 Free testosterone: (ng/mL) average for groups 1 and 2 (before to after surgery): 23.1 ± 3.19 to 32.8 ± 4.37 (4) N/A	N/A

Cayan *et al.* 2000 [13]	468 (132–468)	Compared: Palomo (P), and Microsurgical high inguinal (I)	468 (100%) *P* = 232 I = 236 P: 36/232 (15.51%) I: 5/236 (2.11%) *P* = 0.00	P: 12/132 (9.09%) I: 1/143 (0.69%) *P* = 0.00	(1) Sperm count (before to 12 months after surgery) (mil/mL) P: 30.97 to 34.57; in I: 29.7 to 36.62; Sperm Motility: (before to 12 months after surgery) P: 28.1 to 34.43; in I: 25.6 to 43.47 (2) P: 47/140 (33.57%); I: 57/133 (42.85%) *P* = 0.057 (3) Preoperative FSH (mIU/mL) in P: 7.19; I: 7.25; *P* = s0.51. Preoperative Testosterone (ng/mL) in HVL: 6.83; in I: 6.39; *P* = 0.42 (4) N/A	N/A
Bebars *et al.* 2000 [14]	193 (193)	Compared Palomo (P) and laparoscopic (L)	P: 65 L: 128 P: 7/65 (10.8%) L: 5/128 (3.9%)	P: 3/65 (4.6%) L: 3/128 (2.3%)	(1) Seminal quality'improved' in % of patients. P: 43%; L: 51% 2–4) N/A	(1) In P: postoperative pain in 46 patients (82%) needed one narcotic injection, 10 patients (18%) needed two narcotic injections; six patients (9.2%) had wound erythema and one 1.5%) had wound infection. In L: postoperative pain in 82 patients (87%) needed one narcotic injection, 11 patients (11.7%) needed two narcotic injections; three patients (2.3%) had wound erythema and one (0.8%) had wound infection. (2) N/A (3) General anaesthesia (4) P: Discharged at average of 3.5 days with return to normal activities in 7–14 days; L: discharged at average of 1.3 days with return to normal activities in 3–7 days.
A. Jungwirth 2001 (cited in [5])*	272 (272)	Microsurgical subinguinal: description and results	272 4/272 (1.4%)	1/272 (0.3%)	(1) N/A (2) 130/272 (48%) of patients were able to achieve pregnancy. (3 & 4) N/A	N/A

TABLE 1 Continued

Author/Year	Total no. patients in study, *n* (No. patients in analysis when available)	Technique(s) used and compared	Patients in each sub-group, *n* (% resolved, if available) Patients with recurrence, *n* (%)	Formation of h ydrocele, *n* (%)	Outcome measured: (1) Spermatogenesis (2) Pregnancy rate (3) Hormone levels: testosterone, FSH, etc (4) Testicular volume and growth (vis-à-vis catch-up growth)	Other: (1) Complications (2) Cost-efficacy (3) Anaesthesia (4) Recovery time
Kamal *et al.* 2001 [15]	211 (159)	Microsurgical subinguinal: description and results	N/A N/A	N/A	(1) Sperm concentration; motility; and total motile sperm (preoperative ± SD to postoperative ± SD) 22.5 ± 2.1 to 28.9 ± 3.0 × 10^6/mL; 22.1 ± 1.3 to 33.9 ± 1.9%; and 17.3 ± 2.4 to 37.0 ± 5.0 × 10^6. (2) 76/159 (48%) of couples were able to achieve pregnancy. An additional 16/159 (10%) achieved pregnancy via IVF, and 18/159 (11%) achieved pregnancy via IVF/ICSI. 3 & 4) N/A	N/A
Testini *et al.* 2001 [16]	150 (150)	Microsurgical subinguinal: description and results	150 (100%) 5 (3.3%)	2, 1 transient, 1 permanent (0.7% each)	(1) 120/150 (80%) of patients had improvement in sperm quality. (2) 19/41 (46.3%) of couples experiencing infertility became pregnant. 3 & 4) N/A	(1) Seven (4.7%) patients had transient pain, three (2.0%) had ecchymosis (2) N/A (3) Local anaesthesia (4) Outpatient procedure, postoperative stay: 3–7 h
P. Perimenis 2001 (cited in [5])*	146 (146)	Microsurgical subinguinal: description and results	146 N/A	N/A	(1) 83.2% of patients improved semen quality (2) 67/146 (46.6%) of patients were able to achieve pregnancy overall 3 & 4) N/A	N/A
Cayan *et al.* 2002 [17]	540	Microsurgical inguinal and sub-inguinal: description and results.	N/A N/A	N/A	(1) A positive response (>50% change in total motile sperm count) was seen in 271/540 (50.2%). Overall the total motile sperm count increased from 19.04 ± 1.18 to 27.12 ± 1.49 million, $P < 0.001$ (2) Spontaneous pregnancy was achieved in 163 of 445 (36.6%) of couples. 31% of patients who were candidates only for ICSI due to very low sperm count were able to become candidates for IVF due to improved seminal values postoperatively. 53% of patients who were IVF candidates became candidates for IUI, or spontaneous pregnancy candidates. Of the IUI candidates, 42% became candidates for spontaneous pregnancy and could theoretically conceive without IVF. 3 & 4) N/A	N/A

Penson *et al.* 2002 [4]	N/A	Evaluated cost-effectiveness of the following four treatments: observation, varicocelectomy with IVF; IUI with IVF; and immediate IVF.	N/A N/A	N/A	(1) N/A (2) Pregnancy rate in the four categories: Observational group: 14%, Varicocelectomy and IVF group: 72%, IUI and IVF group: 73%, Immediate IVF group: 61%. 3 & 4) N/A	(1) N/A (2) Cost-effectiveness (average cost, cost per live delivery): Observational: $1996, $13 863; Varicocelectomy with IVF: $31 171, $44 522; IUI with IVF: $36 322, $49 757; Immediate IVF: $39 001, $64 422. 3 & 4) N/A
R. Kumar 2003 (cited in [5])*	100 (50)	Microsurgical subinguinal: description and results	50 1/50 (2%)	0/50 (0%)	(1) 71% of patients had improved sperm count, 60% had normal motility, and 49% had normal morphology. (2) 17/50 (34%) of patients were able to achieve pregnancy. (3 & 4) N/A	N/A
Nabi *et al.* 2004 [18]	71 (45–51)	Percutaneous embolization: description and results.	51 1/51 (1.9%)	N/A	(1) Improvement of seminal quality was only seen in patients whose preoperative semen density was between 10 and 30 (mil/mL). Other categories were not statistically significant. (2) 18/45 (40%) of patients achieved pregnancy at an average of 3.6 years. (3 & 4) N/A	(1 & 2) N/A (3) Local anaesthesia (4) Patients were mobile after 2 h and were discharged with 3 days of NSAIDS.
Ghanem *et al.* 2004 [19]	413 (215 at 3 months follow-up)	Compared: microsurgical subinguinal (MS) and Palomo (P)	MS: 304 P: 109 MS: 0 (0%) P: 8/109 (7%)	MS: 5/304 (1.6%) P: 7/109 (6.4%)	(1) Semen analysis (SA) showed improvement, but no statistical difference between these two groups. (2–4) N/A	1) No complications were noted in this study. (2) N/A (3) MS: local anesthesia. P: spinal or general anaesthesia. (4) No. days off work: MS 1 ± 0.4; P: 3 ± 0.6
Tung *et al.* 2004 [20]	58 (28–31)	Sub-inguinal (Marmar) technique 'with or without magnification': description and results.	28 (100%) 1 (3.2%)	0 (0%)	(1) In the oligo-asthenospermic subgroup ($n = 15$), sperm concentration increased significantly [6.1 ± 4.3] to [24.2 ± 21.0] × 10^6/cc ($P < 0.02$); and motility from [36.4 ± 17.8%] to [45.7 ± 21.9%] ($P < 0.03$). In patients with grade 2 varicocele, the sperm count increased from [19.3 ± 14.9] to [26.4 ± 20.1] × 10^6/cc ($n = 17$, $P < 0.04$). For patients with grade 3 disease ($n = 13$), the sperm count increased from [33.5 ± 19.4] to [38.9 ± 15.8] × 10^6/cc ($P < 0.05$). In grade 3 patients, sperm morphology increased from [54.5 ± 21.2%] to [62.3 ± 19.4%] ($P < 0.03$) and motility from [46.8 ± 22.6%] to [61.8 ± 16.8%] ($P < 0.02$). (2) 6/23 (32%) were pregnant at 7 months (3 & 4) N/A	(1) 1 patient had a haematoma (3.2%), 3/31 (9.7%) did not have complete resolution of preoperative pain after procedure. (2) N/A (3) Spinal anaesthesia (4) N/A

TABLE 1 Continued

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Grober *et al.* 2004 [21]	54 (35 for pregnancy rate)	Microsurgical sub-inguinal technique: description and results in recurrent and persistent varicoceles	54 (100%)	0 (0%)	(1) Median sperm concentration: [15.8 × 10^6 per mL (range: 0 to 226 × 10^6 per mL); mean percent motility: 34.0% ± 3.9%; mean normal morphology: 30.2% ± 4.5%; mean total motile sperm concentration per ejaculate (Semen volume × [Sperm] × % Motility/100): 44.4 ± 14.9 × 10^6 per mL. Postoperative median sperm concentration (26.0 × 10^6 per mL [range: 0 to 796 × 10^6 per mL], $P = 0.02$), mean percent motility (41.3% ± 4.5%, $P = 0.03$), and mean total motile sperm concentration per ejaculate (67.7 ± 16.4 × 10^6 per mL, $P = 0.004$) (2) Pregnancy rate among couples with postoperative follow-up over 24 weeks was 14/35 (40%), including 8/35(23%) cases through natural intercourse, 3/35(9%) cases with IVF/ICSI, and 3/35 (9%) cases with IUI. (3) Preoperative testosterone level: 456 ± 25ng/dL. Postoperative testosterone level: 516 ± 48ng/dL $P = 0.01$ (4) Preoperative mean testicular volume was 17.6 ± 0.6 mL. Postoperative was 18.8 ± 1.3 mL $P = 0.005$	N/A
M. Watanabe 2005 (cited in [5])*	149 (149)	Compared: Palomo (P), Laparoscopic (L), and Microscopic sub-inguinal (MS)	P: 50 L: 33 MS: 66 P: 6/50 (12%) L: 2/33 (6.1%) MS: 0/66 (0%)	P: 5/50 (10%) L: 1/33 (3.03%) MS: 0/66 (0%)	(1) Sperm density was increased in all groups, however sperm motility did not show a statistically significant improvement. (2) P: 18/50 (35.8%); L: 12/30 (40.4%); MS: 34/66 (50.9%) (3 & 4) N/A	1) L: 2 (6.1%) patients had s.c. scrotal emphysema. 2–4) N/A
Gontero *et al.* 2005 [22]	109 (97)	Compared two groups of microsurgical: Inguinal (I) and subinguinal (SI)	I: 50 SI: 47 I: 4/50 (8%) SI: 7/47 (14.9%)	0 at 6 months (0%)	1–4) Semen analysis alterations and/or testicular hypotrophy was noted in 24/49 (48.9%), and 25/50 (50%) in the SI and I groups, respectively, however authors did not reveal this data in their study.	(1) One patient (2%) noticed numbness in the groin area. (2) N/A (3) Local anaesthesia (4) N/A

I. Orhan 2005 (cited in [5])*	212 (212)	Compared two groups of microsurgical: Inguinal (I) and subinguinal (SI)	I: 147 SI: 65 I: 1/147 (0.68%) SI: 2/65 (3%)	I: 0/147 (0%) SI: 0/65 (0%)	(1) Postoperative to preoperative ratio of seminal quality improvement for these two groups were I:42% SI:38%. (2) I: 60/147 (41%); SI: 22/65 (33%) of patients were able to achieve pregnancy. (3 & 4) N/A	N/A
Zucchi *et al.* 2005 [23]	64 (64)	Compared inguinal (I) vs antegrade sclerotherapy (AS) (Tauber procedure)	I: 32 AS: 32 I: 2 (6.25%) AS: 3 (9.36%)	I: 0 (0%) AS: 0 (0%)	1) In patients who underwentTauber procedure there was a significant decline in immotile sperm compared with the surgical group. Overall seminal variables were improved in 40% of patients. Changes in seminal variables (preoperative to postoperative): % Immotile I: 56.5 ± 2.7 to 47.7 ± 3.8; AS: 59.6 ± 4.1 to 46.7 ± 3.9. Sperm count (mil/mL) I: 38 to 45; AS: 34 to 47. Abnormal morphology (abnormal forms, %) I: 59.3 to 37.5; AS: 53.1 to 34.3. 2–4) N/A	(1–3) N/A (4) Outpatient procedure. Average days before returning to normal activity was I: 3–4 days, AS: 1 (next day).
Cayan *et al.* 2005 [24]	100 (100; 33 for testosterone, FSH, and semen analysis)	Compared microscopic (M), loupe magnification (LM), and no (N) magnification.	M: 49 LM: 25 N: 26 M: 0 (0%) LM: 1 (2.9%) N: 3 (8.8%)	M: 0 (0%) LM: 1 (2.9%) N: 2 (5.9%)	(1) Mean sperm concentration ± SE (mil/mL) [21.79 ± 3.61] to [39.62 ± 5.75] $P = 0.007$; Mean motility ± SE (%) [33.61 ± 3.84] to [48.48 ± 3.86] $P = 0.001$ Mean total motile sperm count ± SE (mil) [22.6 ± 5.16] to 64.53 ± 12.3] $P = 0.002$ (2) N/A (3) Mean serum FSH ± SD (mIU/mL) [5.11 ± 3.93] to [4.38 ± 3.75] $P = 0.285$ Mean serum testosterone ± SD (ng/mL) [3.23 ± 2.01] to [4.63 ± 2.69] $P = 0.089$ (4) Size discrepancy was noted before surgery, but not analysed after surgery.	(1) No hematoma or infection, just recurrence and hydrocele. (2–4) N/A
Al-Hunayan *et al.* 2006 [25]	82 (60)	Cost analysis of using two trochars (2T) vs. three trochars (3T).	2T: 30 3T: 30 2T: 0 (0%) 3T: 1 (3.3%)		(1) Increase in sperm count to >5 mil sperm (2T): 70.0%, (3T): 73.3%; Increase in sperm motility to >50% actively motile (2T): 60.0%, (3T): 53.3% (2–4) N/A	(1) 2T: one patient (3.3%) had trochar site bleeding 3T: two patients (6.7%) had trochar site bleeding (2) Procedure can be done with two trochars, reducing the cost of procedure by the cost of one 5mm trochar (3) N/A (4) Mean hospital stay 3T: 1.2 days, 96.7% were ambulatory on day 0 or 1; 2T: 1.1 days 93.3% were ambulatory on day 0 or 1. No statistical significance between the two techniques.

TABLE 1 Continued

Author/Year	Total no. patients in study, *n* (No. patients in analysis when available)	Technique(s) used and compared	Patients in each sub-group, *n* (% resolved, if available) Patients with recurrence, *n* (%)	Formation of h ydrocele, *n* (%)	Outcome measured: (1) Spermatogenesis (2) Pregnancy rate (3) Hormone levels: testosterone, FSH, etc (4) Testicular volume and growth (vis-à-vis catch-up growth)	Other: (1) Complications (2) Cost-efficacy (3) Anaesthesia (4) Recovery time
Zucchi *et al.* 2006 [26]	43 (43)	Evaluated Inguinal (I) and Antegrade sclerotherapy (AS - Tauber) with seminal variables & testicular volume	I: 22 AS: 21 3/43 (7%)	N/A	(1) Sperm count (before to after surgery): 38.2 ± 33.4 to 48.0 ± 33.8; Fast progressive spermatozoa: 9.11 ± 11.2 to 18.9 ± 19.8 (2 & 3) N/A (4) Volume in cm^3 (before to after surgery) 13.4 ± 4.4 to 14.0 ± 4.5	N/A
J. Libman 2006 [27]	369 (369)	Compared Microsurgical technique in patients with bilateral (B) and unilateral (U) varicocele	B: 157 U: 212 N/A	N/A	(1) Seminal variables (before to after surgery, *P* value) B: Semen volume (mL) 3.1 ± 0.1 to 3.2 ± 0.1, $P = 0.93$; Sperm concentration ($\times 10^6$/mL) 20.7 ± 2.0 to 27.3 ± 2.5, $P = 0.005$; Motile sperm (%) 26.1 ± 1.4 to 34.1 ± 1.8 $P = 0.001$; Normal forms (%) 38.5 ± 1.9 to 40.0 ± 2.0 $P = 0.28$. U: Semen volume (mL) 3.5 ± 0.2 to 3.6 ± 0.4 $P = 0.74$; Sperm concentration ($\times 10^6$/mL) 19.0 ± 1.7 to 24.8 ± 2.4, $P = 0.002$; Motile sperm (%) 25.2 ± 1.2 to 29.6 ± 1.4 ($P = 0.006$); Normal forms (%) 33.4 ± 1.5 to 35.2 ± 1.6, $P = 0.04$ (2) Spontaneous pregnancy was achieved in 53/148 (36%) of patients in U group and in 54/110 (49%) of patients in B group, $P = 0.049$ (z test) (3 & 4) N/A	N/A
Al-Kandari *et al.* 2007 [28]	120 (120)	Compared: inguinal (I), laparoscopic (L), and microsurgical subinguinal (M) techniques.	I: 40 (100%) L: 40 (100%) M: 40 (100%) O: 7/40 (17.5%) L: 9/40 (22.5%) M: 1/40 (2.5%)	I: 7/40 (17.5%) L: 10/40 (25%) M: 0/40 (0%)	(1) Sperm concentration (mil/mL) [before to after surgery, *P* value] I: 22 ± 4 to 40 ± 6; L: 21 ± 5 to 41 ± 6; M: 20 ± 5, to 42 ± 7, $P < 0.01$ sperm concentration in all three groups Motility(%): I: 33 ± 4 to 48 ± 4; L: 31 ± 5 to 50 ± 5; M: 34 ± 3 to 52 ± 6, $P < 0.05$ motility in all three groups Normal oval forms (%): I: 34 ± 2 to 36 ± 2, $P = 0.4$; L: 33.3 ± 3 to 35 ± 3 $P = 0.3$; M: 31 ± 4 to 32 ± 5 $P = 0.6$ (2) Pregnancy rates at 1 year: I: 11/40 (28%) L: 12/40 (30%) M: 16/40 (40%), not statistically significant (3) N/A (4) Testicular atrophy was found before surgery in two adolescents in the inguinal group, however this was not a variable that was followed up after surgery.	(1) I: One patient had a scrotal haematoma, which resolved with conservative treatment within 10 days. L: One patient complained of abdominal distention, which resolved within 2 days with conservative treatment. (2) The cost (unilateral, bilateral) was: I: $1800, $2100 L: $2700, $3600 M: $2400, $3000 (3) General anaesthesia (4) Average hospital say (days): I: 1.8; L: 1.6; M: 1.7 Average time to return to work (days): I: 7.2; L: 6.3; M: 5.5

Zampieri *et al.* 2007 [29]	122 (122)	Compared laparoscopic: artery sparing (ASL) and artery non-sparing (ANSL)	ASL: 58/59 (98.3%) ANSL: 63 (100%) ASL: 5/59 (8.5%) ANSL: 0 (0%)	ASL: 1/59 (1.7%) ANSL: 8/63 (12.7%)	1) Patients who underwent ASL had better seminal values before surgery compared with those who underwent ANSL for all variables ($P < 0.01$). 2–4) N/A	1) No complications apart from recurrence and hydrocele formation (2) N/A (3) General anaesthesia (4) N/A
Al-Said 2008 [30]	298 (298)	Compared open inguinal (I), laparoscopic (L), and Microsurgical sub-inguinal (M)	I: 92 L: 94 M: 112 I: 16/92 (17.4%) L: 25/94 (26.6%) M: 4/112 (3.6%)	I: 4/92 (4.3%) L: 8/94 (8.5%) M: 0 (0%)	(1) Sperm concentration in mil/mL (before to after surgery) I: (22 ± 5.2) to (33 ± 6.3) $P = 0.02$; L: (23 ± 4.3) to (38 ± 5.5) $P = 0.02$; M: (17 ± 4.9) to (40 ± 6.2) $P < 0.001$ Sperm motility (%): I: (22 ± 2.6) to 31 ± 2.1) $P = 0.04$; L: (21 ± 2.8) to (30 ± 3.2) $P = 0$ M: (20 ± 2.5) to (34 ± 3.5) $P < 0.001$ % Abnormal sperm I: (65 ± 2.2) to 50 ± 2.9 $P = 0.04$; L: (70 ± 3.4) to (55 ± 2.9) $P = 0.001$ M: (61 ± 2.8) to (56 ± 3.1) $P = 0.04$ (2) Pregnancy rate at 1 year O: 29/92 (31%), L: 31/94 (33%) M: 43/112 (38%) (3 & 4) N/A	(1) Complications in I: Two patients had wound infections, two had scrotal haematomas, and four had scrotal pain L: Six patients had scrotal pain, no infection or haematoma M: Two patients had wound infections, two had scrotal haematomas and four had scrotal pain. (2) N/A (3) General anaesthesia (4) Outpatient procedure. Average time to return to work (days): I:9; L:8; M:8 Results not statistically significant ($P = 0.5$)
Boman 2008 [31]	610 (82–118)	Compared microsurgical varicocelectomy (M) with observation (O) in terms of pregnancy rates and seminal quality	M: 69 O: 49 N/A	N/A	(1) Seminal quality (before to after surgery) Semen vol (mL): 3.3 ± 4.1 to 2.9 ± 1.5 ($P > 0.05$); Sperm concentration ($\times 10^6$/mL): 48.0 ± 29.7 to 36.6 ± 26.0 ($P = 0.027$); Sperm motility (% motile): 23.4 ± 10.4 to 33.2 ± 20.6 ($P = 0.0002$); Sperm morphology (% normal forms): 42.8 ± 9.5 to 47.3 ± 17.6 ($P > 0.05$); Total motile sperm count: ($\times 10^6$): 29.6 ± 27.4 to 39.0 ± 45.5 ($P = 0.047$); (2) Spontaneous pregnancy rate M: 45/69 (65%); O: 16/49 (32%); The difference between M and O was not significant, however, patients who had ICSI showed better outcomes in observational group M: 11%; O: 32% (3) FSH levels were not statistically different between the two groups before surgery and not tested after surgery. (4) N/A	N/A

TABLE 1 Continued

Author/Year	Total no. patients in study, *n* (No. patients in analysis when available)	Technique(s) used and compared	Patients in each sub-group, *n* (% resolved, if available) Patients with recurrence, *n* (%)	Formation of h ydrocele, *n* (%)	Outcome measured: (1) Spermatogenesis (2) Pregnancy rate (3) Hormone levels: testosterone, FSH, etc (4) Testicular volume and growth (vis-à-vis catch-up growth)	Other: (1) Complications (2) Cost-efficacy (3) Anaesthesia (4) Recovery time
Zampieri *et al.* 2009 [32]†	225 (221)	Compared: laparoscopic artery preserving (L) and microsurgical inguinal (M)	N/A N/A	N/A	(1) L: 13/32 (40.6%) and M: 14/24 (58.3%) had normalization of semen quality. (2 & 3) N/A (4) L: Testicular volume (before surgery to 18 months after surgery) Left (6 ± 2 cm^3) to (7 ± 1.5 cm^3); Right (8 ± 1.2 cm^3) to (9.5 ± 2 cm^3) 84/97 (86.6%) had statistically significant catch-up growth ($P < 0.05$). At 18 months after surgery, only 38/84 (45.2%) of patients with catch-up growth had equal bilateral testicular volumes. M: Testicular volume (before surgery to18 months after surgery) Left (7 ± 1.7 cm^3) to (8 ± 0.7 cm^3); Right (8 ± 2.0 cm^3) to (10.5 ± 2.1 cm^3) 99/124 (79.8%) had statistically significant catch-up growth ($P < 0.05$). At 18 months after surgery, only 34/99 (34.3%) of patients with catch-up growth had equal bilateral testicular volumes.	(1) Persistence, recurrence, and hydrocele formation were exclusion criteria and these patients were not included (2–4) N/A
Fayez *et al.* 2010 [33]	155 (155)	Compared inguinal/ Ivanissevich (I), scrotal sclerotherapy/ Tauber's (T), and subinguinal sclerotherapy (SS) in terms of sperm variables and pregnancy rates	I: 55 (100%) T: 51 (100%) SS: 49 (100%) N/A	I: 3 (5.5%) T: 0 (0%) SS: 0 (0%)	(1) Sperm count and motility increased in all groups. (2) Pregnancy rates were: I: 11/55 (20%) T: 7/51 (13.73%) SS: 6/49 (12.24%) (3 & 4) N/A	N/A

*N/A, not available. *Extrapolated from meta-analysis in Cayan et al. 2009 [5]; †Adolescent study where author measured fertility factors.*

repair in three techniques: (i) inguinal (unilateral and bilateral): $1800 and $2100; (ii) laparoscopic: $2700 and $3600; (iii) microscopic subinguinal: $2400 and $3000.

The method of anaesthesia used can add to costs and we found that several methods were employed: general anaesthesia was used in 11, local anaesthesia in five, and spinal anaesthesia in two studies (Table 1).

Another factor involved in cost is the recovery time. For recovery time, authors reported hospital stay and time to return to work/normal activities (in days) per procedure (Table 5).

DISCUSSION

TO TREAT OR NOT TO TREAT

Before surgical intervention can be suggested, a surgeon must take the appropriate steps in the diagnosis of varicocele. Routine evaluation of infertile men with varicoceles should include a medical and reproductive history, physical examination and a minimum of two semen analyses. Indications for varicocelectomy are: (i) the varicocele is palpable on physical examination of the scrotum; (ii) the couple has known infertility; (iii) the female partner has normal fertility or a potentially treatable cause of infertility; (iv) the male partner has abnormal semen quality or abnormal results from sperm function tests [6]. All four criteria must be met to make a case for surgical intervention. Subclinical varicoceles do not have an impact on fertility [36] and are not regularly treated when found in isolation of other criteria. Decreased sperm number, decreased motility and increased percentage of abnormal forms are all complications that lead to decreased fertility. Increased temperature attributable to venous stasis and decreased efficacy of the countercurrent cooling system is one of the main causes of germ cell apoptosis, a leading cause of these seminal aberrations, and damage to sperm chromatin is presumably attributable to increased oxidative stress and apoptosis of germ cells [35,37]. Varicocelectomy eliminates venous stasis and returns testicular blood flow to the original state [2].

CRITICAL APPRAISAL OF TECHNIQUES

Note: the following descriptions are compilations from Hopps & Goldstein's: 'AUA update series on varicocelectomy' [2]; Paduch and Skoog's 'Current management of adolescent varicocele' [37] and Wein: Campbell-Walsh Urology 9th edition 'procedures to improve sperm production' [38].

The benefits of the Palomo procedure are the low cost, and that it ligates high enough to avoid multiple branching veins. There are usually only 2–3 veins seen at this location making it easier for the surgeon. There is also no opportunity to ligate the collateral veins that branch out of the bundle inferior to the operating field in the procedure, which can lead to a higher recurrence rate. While testicular atrophy after artery ligation has been described in the literature, it was not seen in any of the manuscripts analysed. There are several modifications to this procedure, which include artery and lymphatic preservation, but this technique still has a higher incidence of varicocele recurrence and hydrocele formation than any other.

The inguinal procedure has the benefit of being able to ligate collaterals as they come out from the inguinal ring, and is an easier approach in obese patients. The collaterals seen at this level give the surgeon an opportunity to ligate the external spermatic veins, which cannot be done in a high ligation

TABLE 2 Pregnancy rate, recurrence of varicocele and formation of hydrocele, arranged by pregnancy rate in descending order

Surgical technique:	No. of studies analysed:	% Pregnancy Rate (range)	% Recurrence of varicocele (range)	% Formation of hydrocele (range)
Microsurgical subinguinal	13	44.75 (33.8–51.5)	2.07 (1.4–14.8)	0.72 (0.3–1.6)
Microsurgical inguinal	6	41.78 (40.8–42.8)	9.47 (0.7–15.2)	0.29 (0.0–0.7)
Palomo	4	34.21 (33.5–36)	12.5 (7.3–15.5)	7.58 (4.6–9.0)
Radiological embolization	7	31.93 (12.2–40)	4.29 (1.9–9.3)	N/A*
Inguinal	6	30.06 (20–31.5)	15.65 (3.57–17.5)	7.47 (4.3–17.5)
Laparoscopic	9	27.53 (13.1–40)	11.11 (4.0–26.5)	7.57 (1.7–12.7)
Subinguinal†	1	26.09 (26.09)	3.57 (3.57)	0

*N/A, not available. *Hydroceles are not typically seen with embolization procedures; †Only one author met the inclusion criteria, and several patients in this study had the repair 'with or withouht microscopic magnification' [20].*

TABLE 3 Hormonal changes after varicocelectomy

Author		Preoperative FSH	Postoperative FSH	Preoperative testosterone (ng/mL)	Postoperative testosterone (ng/mL)	*P* (testosterone only)
Cayan *et al.* 1999 [12]*	Group 1	7.37 ± 1.74	6.58 ± 1.54	5.63 ± 1.4	8.37 ± 8.37	0.01
	Group 2	24.0 ± 3.3	15.1 ± 3.24	N/A†	N/A†	N/A†
Grober *et al.* 2004 [21]		N/A	N/A	4.56 ± 0.25	5.16 ± 0.48	0.01
Cayan *et al.* 2005 [24]		5.11 ± 3.93	4.38 ± 3.75	3.23 ± 2.01	4.63 ± 2.69	0.089

**Group 1: Preoperative FSH was <10; Group 2: Preoperative FSH was >10; †The author evaluated testosterone as an average of the entire study and did not separate into two groups. See above box for testosterone measurements.*

as with the Palomo technique. There have been modifications to this technique as well: the term 'modified inguinal or modified Ivanisevich' is typically reserved for artery sparing, but injection of dye into the lymphatics has also been used for the lymphatic-sparing technique. In this technique the ileoinguinal nerve must be identified and preserved. An operating microscope may be used to assist in dissection.

While laparoscopy has fewer recurrent varicoceles and hydroceles than non-microsurgical open approaches, it is still used less frequently because of the need for an experienced laparoscopic surgeon and the higher cost than for the open techniques, including the microscopic technique. Laparoscopic varicocelectomy had more reported complications and is more invasive than other techniques. Local anaesthesia can be used in open surgical approaches, but laparoscopy will always require general anaesthesia with complete control over the respiratory system and acid-base status of the patient.

The embolization/sclerosing techniques of the radiological approach have the benefit of being the least invasive with the ability to visualize radiologically collateral veins which may not have been seen during surgery. The high cost and high failure rate are factors that need to be considered for each patient when evaluating if this technique is appropriate.

TABLE 4 Testicular size

Author and year	Mean ± SD preoperative testicular size, cm^3		Mean ± SD postoperative testicular size, cm^3		*P*
Grober *et al.* [21]	17.6 ± 0.6		18.8 ± 1.3		=0.005
Zucchi *et al.* 2006 [26]	13.4 ± 4.4		14.0 ± 4.5		<0.05
Zampieri 2009 [32]*					
Group 1:	L: 6 ± 2.0	R: 8 ± 1.2	L: 7 ± 1.5	R: 9.5 ± 2	N/A
Group 2:	L: 7 ± 1.5	R: 8 ± 2	L: 8 ± 0.7	R: 10.5 ± 2.1	

**Adolescent study where Group 1 = laparoscopic artery preserving; Group 2 = microsurgical with venous bypass: L, left testicle; R, right testicle.*

TABLE 5 Recovery time

Technique	Author and year	Days in hospital*	Days to return to normal activity
Palomo	Bebars *et al.* 2000 [14]	3.5	7–14
	Ghanem *et al.* 2004 [19]	0	3
Inguinal	Zucchi *et al.* 2005 [23]	0	3–4
	Al-Kandari *et al.* 2007 [28]	1.8	7.2
	Al-Said 2008 [30]	0	9
Microsurgical subinguinal	Testini 2001 [16]	0	N/A
	Ghanem 2004 [19]	0	1
	Al-Kandari *et al.* 2007 [28]	1.7	5.5
	Al-Said 2008 [30]	0	8
Laparoscopic	Tan 1995 [7]	0	N/A
	Bebars 2000 [14]	1.3	3–7
	Al-Kandari *et al.* 2007 [28]	1.6	6.3
	Al-Said 2008 [30]	0	8
Radiological	Nabi 2004 [18]	0	N/A
	Zucchi 2005 [23]	0	1

*N/A, not available. *0 = outpatient procedure unless otherwise specified.*

SPECIAL CONSIDERATIONS FOR COMPLICATIONS

Hydroceles are common problems and occur between 0.29 and 7.58% of patients depending on the approach (Table 1). The rate of hydrocele formation is directly related to lymphatic damage. The testicular lymphatics run posteriorly to the vascular bundle and are easily damaged if not isolated or identified and preserved [30]. Another complication that is commonly overlooked in non-lymphatic-sparing techniques is pseudohypertrophy (perceived testicular enlargement resulting from interstitial oedema); In 2003 Kocvara *et al.* [39] reported that 32% of patients who underwent non-lymphatic-sparing surgery had postoperative evidence of enlargement of testicle to a size greater than the contralateral side. Biopsy of these enlarged testicles showed marked oedema of intertubular tissue and reduced spermatogenesis. This led the author to conclude that the marked increase in testicular size after varicocelectomy was attributable to oedema, not catch-up growth in patients where lymphatics were divided. Furthermore, measuring postoperative testicular size may be inaccurate in non-lymphatic-sparing techniques and care should be taken to preserve lymphatics when measurements take place.

With the radiological technique most authors would differentiate between failure (persistence) and recurrence (Table 1). Failure/persistence was not reported for the vast majority of surgical approaches and this lack of data meant we were unable to report on this. It is an important variable to analyse, and doing so would reveal which technique is most arduous and leads most frequently to failed varicocele dissection and ligation.

For each approach evaluated one or more authors reported varicocelectomy as an outpatient procedure, and in the absence of major complications, it would appear that this is becoming standard. Recovery time varied between different studies and within each approach, with return to work ranging from 1–2 days to 2 weeks. Radiological embolization resulted in a shorter time to discharge and return to work compared with other techniques, and microsurgical subinguinal had the best recovery time of the surgical techniques (Table 1). Hospital stay and return to work time for the other techniques was too varied to analyse.

While some recent studies have shown a statistically significant increase in serum testosterone after varicocelectomy, other publications show no change. In the present review two authors reported a significant increase and one did not [12,21,24] (Table 3). While an increase in serum testosterone may show an improvement of leydig cell function, this may not be an accurate measure of improved spermatogenesis because it is intratesticular testosterone, not serum testosterone, that influences spermatogenesis [28]. FSH levels followed the expected trend: a postoperative decrease to normal or semi-normal ranges in level (Table 1).

Complications from laparoscopic surgery far exceeded any other method with added risks associated with pneumoperitoneum (Table 1). While some authors have described gasless laparoscopy with a trochar balloon [40] this is not standard practice because of the longer operating time, greater costs and lack of training in this new approach, and still needs further development to become an effective treatment option. In general, complications after open surgery were less common than with laparoscopy. Wound infections and erythema were common, but are inherent in any surgical procedure. No authors reported testicular atrophy attributable to testicular artery ligation, and collateral arterial blood supply appeared to be adequate for perfusion in patients who underwent a Palomo/artery non-sparing procedure.

The use of loupe magnification or an operating microscope has been shown to reduce complications, and in 2005 Cayan *et al.* [24] published a study that directly compared these factors and showed that rates of varicocele recurrence and hydrocele formation steadily decreased with increasing magnification.

Cost-efficacy studies clearly showed that varicocelectomy by itself, or in conjunction with IVF, is more a cost-effective option than more technologically advanced and expensive fertility treatments [10,14]. The 2007 Al-Kandari [28] study indicated that inguinal and laparoscopic approaches tend to have a lower operative cost but, in terms of pregnancy rates, varicocele recurrence and hydrocele formation, they are not as effective as microsurgical subinguinal approaches. Anaesthesia is not an insignificant part of the cost involved, and as more surgeons use local or spinal anaesthesia and more papers are published on series involving these anaesthesia methods, perhaps the overall will decrease.

In addition to gasless laparoscopy, there is another new technique worth mentioning. In 2004 Fisch *et al.* [41] introduced the use of a Keith needle to dissect and isolate the artery, demonstrating the ability selectively to remove the entirety of the internal spermatic venous plexus while leaving the artery and lymphatics virtually untouched. Innovations like this are easy to teach, do not have the associated cost of laparoscopy, and do not involve a time-consuming microscopic dissection.

CONCLUSIONS

While multiple surgical approaches, and radiological embolization techniques exist for the treatment of varicocele, the microsurgical inguinal and microsurgical subinguinal approaches have been shown to be the most efficacious and cost-effective in treating varicocele. Higher pregnancy rates, lower varicocele recurrence, and less hydrocele formation put these two approaches at the forefront of surgical treatment options for infertile men with varicocele. The use of an operating microscope allows surgeons to perform selective lymphatic- and artery-sparing varicocelectomy and gives patients the best chance for future pregnancy. Further research is still needed to analyse and prospectively study new techniques and innovations in current techniques for both adults and adolescents.

CONFLICT OF INTEREST

None declared.

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Abbreviations: **IVF**, *in vitro* fertilization; **ICSI**, intracytoplasmic sperm injection; **IUI**, intrauterine insemination.