The Effects of Varicocelectomy on Testicular Arterial Blood Flow: Laparoscopic Surgery versus Microsurgery

Minghui Zhang,[1,2] Lizhen Du,[2] Zhijun Liu,[2] Hengtao Qi,[3] Qiang Chu[2*]

Purpose: To investigate the long term effects of laparoscopic varicocelectomy (LV) and microsurgical subinguinal varicocelectomy (MV) on ipsilateral testicular microcirculation using Color Doppler Flow Imaging (CDFI).

Materials and Methods: A total of 29 patients with left varicocele who underwent LV and 30 patients who underwent MV were examined with CDFI for intratesticular flow parameters before and at 3- and 6-month after surgery. Preoperative and postoperative semen parameters were also evaluated.

Results: The mean values of peak systolic velocity, pulsatility index (PI) and resistive index (RI) of capsular artery (CA) and intratesticular artery (ITA) decreased significantly after LV and MV, whereas no significant change was observed in end-diastolic velocity. Comparing between two groups, the PI and RI values of left CA and ITA on 3rd month and of ITA on 6th month postoperatively in MV group were significantly lower than those in LV group. LV and MV resulted in a statistically increase in the sperm density, morphology and total motile sperm count. Moreover, the PI and RI values of ipsilateral CA and ITA seemed negatively correlated with sperm quality.

Conclusion: A significant improvement occurs in testicular blood supply and sperm parameters after either LV or MV, among MV advances an early and a more obvious hemodynamics promotion than LV. The values of RI and PI of ipsilateral CA and ITA are two important indexes for the prognosis after varicocelectomy.

Keywords: laparoscopy; microsurgery; postoperative complications; spermatic cord; varicocele; surgery; treatment outcome.

INTRODUCTION

Varicocele is defined as the hemodynamic impairment of testicular venous network with continuous blood reflux in pampiniform plexus and characterized by the abnormal dilation and retrograde flow in the affected veins.[1] The estimated incidence of varicocele is about 20% in the general population rising to almost 40% in subfertile men.[2] The effects of varicocele include reduced ipsilateral testicular volume, impaired sperm production ranging from oligozoospermia to complete azoospermia, and reduced fertility.[3] Although proposed factors, as elevated testicular temperature caused by increased testicular blood flow, venous stasis secondary to increased venous pressure, reflux of adrenal/renal metabolites, hormonal imbalance and directly injuries due to the generation of excessive reactive oxygen species, may partly explain the impaired spermatogenesis, the exact mechanisms of the deleterious effects of varicocele on spermatogenesis are poorly understood.[3-6]

The method for treatment of varicocele is mainly varicocelectomy, though various approaches exist, including traditional open inguinal (Ivanissevich)/high retroperitoneal (Palomo), laparoscopic, microscopic inguinal and microscopic subinguinal surgery. Regardless of these different approaches, changes in semen parameters after varicocelectomy have been well demonstrated, with improved sperm concentration, motility and morphology and increased total motile sperm counts (TMSC) and pregnancy rates.[2,3,7] Nevertheless, pathophysiology of this relationship between improved semen quality and varicocelectomy remains controversial.[8] It is hypothesized that impaired venous drainage causes increase in venous pressure of the spermatic veins. The condition of venous stasis may decrease the arterial blood supply and microperfusion of the testes by down-regulating arterial inflow to maintain the homeostasis of the intratesticular vascular pressure, thus inducing hypoxia and deficiency in testicular microcirculation.[2,9] Besides, it is thought that, this hypoxia could be responsible for defective energy metabolism at mitochondrial levels causing dysfunction of both Leydig and germinal cells.[4,5,10]

The arterial supply to the testis has three major components: the testicular artery (TA), the cremasteric artery and the deferential artery, among which two thirds are supplied by TA. TA divides into two branches in testis, while the capsular artery (CA) continues in the surface of

[1] Department of Ultrasound, Cardiovascular Institute and Fuwai Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing 100037, China.
[2] Department of Ultrasound, Qingdao Municipal Hospital, Qingdao University, Qingdao 266071, China.
[3] Department of Ultrasound, Shandong Medical Imaging Research Institute, Shandong University, Jinan 250021, China.
* Correspondence: Department of Ultrasound, Qingdao Municipal Hospital, Qingdao University, No. 5, Donghaizhong Rd., Qingdao 266071, China.
Tel: +86 532 88905330; Fax: +86 532 85968434. E-mail: qdultrasound@gmail.com.
Received March 2014 & Accepted June 2014

Table 1. Demographic and clinical characteristics of patients in study groups.

Variables	LV Group (n = 29)	MV Group (n = 30)	Total (n = 59)	*P* Value
Patients number	29	30	59	
Grade of varicocele				
Grade II	20	19	39	
Grade III	9	11	20	.785
Chief complaint				
Pain	10	9	19	
Mass	13	9	22	
Infertility	6	12	18	.251
Age (range, years)	18-35	18-35	-----	
Age (median, years)	23	24	-----	.484

Abbreviations: LV, laparoscopic varicocelectomy; MV, microsurgical subinguinal varicocelectomy.

the testis and the intratesticular artery (ITA) in the parenchyma and deep.[11] Previous studies indicate that Color Doppler Flow Imaging (CDFI) is well established to illustrate macro-microvascularity and therefore perfusion of the testis.[10-12] The arterial flow velocities (peak systolic velocity, PSV, and end diastolic velocity, EDV) and the resistance indices against this flow (resistive index, RI, and pulsatility index, PI) in the testis can be accurately measured with CDFI technique.

In our hospital, microsurgical subinguinal varicocelectomy (MV) has been the principle method in the latest two years, however, laparoscopic varicocelectomy (LV) was the mainstream before. The aim of this study is to investigate the effects of varicocelectomy, both LV and MV, on testicular arterial blood flow using CDFI, and to clarify whether the present MV is superior to the previous LV.

MATERIALS AND METHODS

Study Patients

A total of 59 adults with clinical left varicocele and with various scrotal complaints were included (**Table 1**). The varicocele had been detected on physical examination and scrotal ultrasonography. No comorbidities such as hypertension, diabetes, psoriasis, or other internal diseases existed, besides bilateral/subclinical/recurrent varicocele, history of varicocelectomy and azoospermia, any scrotal pathology other than varicocele were also excluded. LV was performed during May 2010 and November 2011, and MV was performed since January 2012. The same surgeon (ZL) performed either of the two operations in all patients, and all patients were obligated to have follow-up visits including physical and sonographic examinations 3 and 6 months after surgery. Informed consent was obtained from all patients, and the study protocol was approved by the ethics committee of our hospital (QMH-20100046, QMH-20120013).

Table 2. Testicular volume (mL, mean ± SD) of patients in study groups.*

Variables	LV Group	MV Group
Patients number	29	30
Preoperative (Left)	12.71 ± 2.16	12.63 ± 3.08
3 months	13.01 ± 2.96	12.87 ± 2.91
6 months	12.97 ± 2.67	12.83 ± 3.14
Preoperative (Right)	13.04 ± 3.02	12.76 ± 3.03
3 months	12.94 ± 3.40	12.73 ± 3.29
6 months	13.11 ± 3.12	12.89 ± 3.33

Abbreviations: LV, laparoscopic varicocelectomy; MV, microsurgical subinguinal varicocelectomy.
* All *P* values are statistically non-significant ($P > .05$).

Color Doppler Ultrasonographic Examination

All patients were examined via GE Logiq 9 Ultrasound System using a 9.0~12.0 MHz linear-array transducer (GE Medical Systems, LLC, Milwaukee, WI, USA) in the supine position during normal respiration and during Valsalva maneuver. The diagnostic criteria for varicocele were as the common view.[13] All patients were studied between 16:00 and 18:00 pm in a warm quiet room and they rested for at least 15 min before the ultrasonography. Routine scrotal ultrasonography was analyzed for testicular size. The volume of the testis was calculated using the formula for a prolate ellipse ($A \times B \times C \times 0.52$), where A, B and C are the 3 longest diameters of the testis.[14] The left intratesticular blood flow parameters were measured just prior to surgery and were repeated at 3rd and 6th months follow-up, moreover parameters of the right side were measured as control. Built-in software was used for automatic calculation, on the frozen spectral display, of the PSV, EDV, RI and PI on spectral Doppler waveforms. RI was calculated as [(PSV-EDV)/PSV]. PI was calculated as [(PSV-EDV)/TAMaxV], with TAMaxV = time-averaged maximum flow velocity. The Doppler sample window was set at 1 mm. On each Doppler tracing, measurements were performed only when the waveform modulation and amplitude remained stable on at least three consecutive cardiac cycles. All the exams were done by the same researcher (MZ) and reevaluated by another researcher (QC). We had calculated a κ between the researcher ($P = .910$).

Surgery

Laparoscopic Varicocelectomy (LV)

Patients were placed in a right lateral low lithotomy position under general anesthesia. Three ports (one 10- and two 5-mm trocars) were placed in a triangle formation, with a camera port (10 mm) just below the umbilicus and the other two ports at the lateral border of each rectus abdominis muscle. After dissecting the adhesion between the intestine/mesentery and the varicoceles if exist, a retroperitoneal incision was made in the lateral aspect from the point 3 cm superior to the internal inguinal ring along

Table 3. Comparison of preoperative and postoperative blood flow parameters in both testes (LV group, n = 29).*

Variables	Capsular Artery				Intratesticular Artery			
	PSV (cm/s)	EDV (cm/s)	PI	RI	PSV (cm/s)	EDV (cm/s)	PI	RI
Preoperative (Left)	10.71 ± 3.53	3.62 ± 1.67	1.07 ± 0.19	0.62 ± 0.09	7.23 ± 1.17	3.32 ± 0.77	0.91 ± 0.11	0.59 ± 0.06
3 months	9.17 ± 1.97**	3.51 ± 1.39	0.98 ± 0.11**	0.55 ± 0.06‡	6.77 ± 1.04	3.21 ± 0.69	0.82 ± 0.09†	0.55 ± 0.05†
6 months	9.18 ± 1.92**	3.52 ± 1.47	0.92 ± 0.09‡§	0.53 ± 0.05‡	6.47 ± 0.98†	3.19 ± 0.73	0.79 ± 0.07‡	0.54 ± 0.04‡
Preoperative (Right)	9.52 ± 3.96	3.59 ± 1.52	1.11 ± 0.34	0.60 ± 0.08	7.06 ± 0.97	3.26 ± 0.67	0.83 ± 0.11	0.54 ± 0.07
3 months	9.53 ± 3.66	3.64 ± 1.40	1.02 ± 0.28	0.59 ± 0.06	7.07 ± 1.01	3.21 ± 0.59	0.86 ± 0.10	0.56 ± 0.07
6 months	9.51 ± 3.38	3.55 ± 1.05	1.05 ± 0.27	0.61 ± 0.09	7.03 ± 1.09	3.11 ± 0.71	0.87 ± 0.13	0.57 ± 0.09

Abbreviations: LV, laparoscopic varicocelectomy; PSV, peak systolic velocity; EDV, end diastolic velocity; PI, pulsatility index; RI, resistive index.
* Data are presented as mean ± SD.
** $P < .05$ compared with the preoperative data.
† $P < .01$ compared with the preoperative data.
‡ $P < .001$ compared with the preoperative data.
§ $P < .05$ data of 6th month postoperatively compared to that of 3rd month, $P = .0269$ exactly.

the testicular vessels. The lymphatic vessels and TA were identified and likewise preserved. The para-arterial veins that paralleled or sandwiched the TA were separated, ligated by Hem-o-lok clips (Weck Closure Systems, Research Triangle Park, NC, 27709, USA) and cut.[1] Patients were discharge on the second post-operative day (POD2).

Microsurgery Subinguinal Varicocelectomy (MV)

Patients were placed in the supine position after induction of adequate spinal anesthesia. A 2.5 cm subinguinal incision was made and the testicle was then delivered. Through the operating microscope at 6-15 × magnification, the vas deferens, vasal vessels, TA (or TAs) and as lymphatic channels as possible were preserved, all internal spermatic veins were identified and dissected and then ligated with 4-0 Mersilk sutures (Ethicon Inc., Shanghai, China). The spermatic cord was then repeatedly examined until no veins other than deferential veins remain. The gubernaculum was also thinned sufficiently so that veins on both sides can be identified and ligated.[10] The spermatic cord was last returned to its bed. Incision was closed layers by layers, while skin closure was performed with sterile strip enforcement. Patients were discharge on the next day (POD1).

Semen Analysis

Semen specimens were collected on site after two-five days of sexual abstinence preoperatively and repeated at 6th month after surgery, and only from the subfertile and patients who were married and receptive to the test, as semen collection by masturbation was somehow ridiculous for the virgin boys. Sperm concentration, motility and morphology were assessed using World Health Organization (WHO) 2010 manual for the Examination and Processing of Human Semen.[15] TMSC (i.e., ejaculate volume × concentration × motile fraction) was calculated. A 50% or more TMSC increase from baseline was accepted

Table 4. Comparison of preoperative and postoperative blood flow parameters in both testes (MV group, n = 30).*

Variables	Capsular Artery				Intratesticular Artery			
	PSV (cm/s)	EDV (cm/s)	PI	RI	PSV (cm/s)	EDV (cm/s)	PI	RI
Preoperative (Left)	11.11 ± 4.04	3.79 ± 1.76	1.11 ± 0.20	0.60 ± 0.12	7.13 ± 1.50	3.30 ± 0.85	0.97 ± 0.17	0.58 ± 0.08
3 months	9.28 ± 2.54**	3.62 ± 1.67	0.91 ± 0.14‡#	0.52 ± 0.05†#	6.43 ± 0.99**	3.29 ± 0.73	0.69 ± 0.17‡&	0.49 ± 0.06‡&
6 months	9.17 ± 2.83**	3.65 ± 1.93	0.92 ± 0.15‡	0.54 ± 0.06**	6.58 ± 1.16	3.31 ± 0.69	0.67 ± 0.15‡&	0.50 ± 0.07**$
Preoperative (Right)	9.17 ± 3.34	3.44 ± 1.60	1.01 ± 0.44	0.59 ± 0.12	7.22 ± 0.87	3.27 ± 0.76	0.87 ± 0.12	0.55 ± 0.07
3 months	9.23 ± 3.82	3.61 ± 1.54	1.13 ± 0.39	0.62 ± 0.11	7.19 ± 0.91	3.20 ± 0.50	0.84 ± 0.17	0.53 ± 0.06
6 months	9.21 ± 3.11	3.57 ± 1.37	1.15 ± 0.31	0.61 ± 0.13	7.23 ± 1.00	3.21 ± 0.61	0.88 ± 0.13	0.54 ± 0.08

Abbreviations: MV, microsurgical subinguinal varicocelectomy; PSV, peak systolic velocity; EDV, end diastolic velocity; PI, pulsatility index; RI, resistive index.
* Data are presented as mean ± SD.
** $P < .05$ compared with the preoperative data.
† $P < .01$ comparing to the preoperative data
‡ $P < .001$ comparing to the preoperative data.
Data comparison of the same time point between the two groups, Table 3 and Table 4:
# $P < .05$; $ $P < .01$; & $P < .001$.

Table 5. Pre- and postoperative semen parameters in study groups.

Parameters	LV Group (n = 12)			MV Group (n = 14)		
	Preoperative	Postoperative	*P* Value	Preoperative	Postoperative	*P* Value
Total motile sperm counts (million)	63.69 ± 16.60	92.72 ± 17.73	.0004	60.11 ± 18.25	96.08 ± 20.44	< .0001
Sperm count (million/mL)	34.23 ± 9.30	53.91 ± 12.06	.0002	32.74 ± 9.41	56.22 ± 13.00	< .0001
Motility (%)	52.83 ± 12.96	56.44 ± 17.73	.5748	50.14 ± 10.99	57.35 ± 17.05	.1251
Normal morphology (%)	29.52 ± 13.69	43.59 ± 15.24	.0265	27.06 ± 10.97	40.31 ± 13.67	.0072

Abbreviations: LV, laparoscopic varicocelectomy; MV, microsurgical subinguinal varicocelectomy.

as a significant improvement in the semen parameters.[12]

Statistical Analysis

PASW Statistics version 18.0 software (IBM SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Results were expressed as the mean ± standard deviation. The demographic data were compared using a chi-square or Mann-Whitney *U* test, and pre- and postoperative data were compared using a Student's *t*-test for paired samples. A *P* value of < .05 was considered statistically significant.

RESULTS

Patients' information is summarized in **Table 1**. No operative or postoperative complication was observed within six months, and no post-operative varicocele recurrence was identified. No participants were lost to follow up, as they were all local citizens. In LV group, 50% (5/10) of patients with the chief complaint of pain and 84.6% (11/13) of patients with the complaint of mass were cured, and the rest were relieved; while in MV group, the cure rate was 88.9% (8/9) no matter complaining of pain or mass, and then the relieve rate was 11.1% (1/9). No couple achieved spontaneous pregnancy within the follow-up in either group.

The mean testicular volumes for the LV and MV groups are presented in **Table 2**. There was no statistically significant difference among the pre- and postoperative values within either LV or MV group (*P* > .05). There was also no statistically significant difference in those values for the testes between the two groups (*P* > .05).

All the preoperative and postoperative blood flow parameters in both testes are listed in **Table 3** and **Table 4**. Within each (LV or MV) group, the values of RI, PI and PSV in the left ITA and CA decreased significantly after surgery (*P* < .05), among which the values of RI and PI seemed more sensitive than PSV (with smaller *P* values), and those of 6th month were insignificantly lower (*P* > .05) than 3rd month postoperatively except PI of CA in LV group (*P* < .05). No significant change was observed in EDV (*P* > .05). No differences were detected in the right ITA and CA between the preoperative and postoperative blood flow parameters (*P* > .05). Comparing between two groups, the initial (preoperative) parameters were statistically equal (*P* > .05), but the interim data (3rd month postoperative), the values of PI and RI of CA and ITA, in MV group were significantly lower than those in LV group (*P* < .05), moreover in the ultimate (6th month postoperative) data, the values of PI and RI of ITA were also lower in MV group (*P* < .01). Of study participants 41.4% (12/29) and 46.7% (14/30) of patients underwent semen analyses in LV and MV groups, respectively (**Table 5**). In both groups, sperm density, percent normal morphology, and TMSC were improved after surgery (*P* < .05), however, sperm motility remained unchanged (*P* > .05). TMSC was the most important indicator of sperm quality, and ≥ 50% TMSC increase postoperatively was considered as a meaningful improvement.[12] According to this criteria, TMSC improved (≥ 50%) in 66.7% (8/12) and 78.6% (11/14) of patients in LV and MV groups, respectively, the rest remained unchanged (< 50% increase). The preoperative and postoperative mean CDFI values were respectively listed in **Table 5** in the 19 patients with TMSC improvement versus in the remaining 7 patients with no semen improvement. In TMSC improved subgroup, the values of PI and RI of ipsilateral CA and ITA were significantly decreased (*P* < .05), whereas in TMSC unchanged subgroup, the values of PI and RI of

Table 6. Correlation between pre- and postoperative TMSC and ipsilateral CDFI parameters.

Parameters	TMSC Improved Subgroup (n = 19)			TMSC Unchanged Subgroup (n = 7)		
	Preoperative	Postoperative	*P* Value	Preoperative	Postoperative	*P* Value
TMSC (million)	58.91 ± 14.47	96.27 ± 16.37	< .0001	69.50 ± 15.22	89.81 ± 18.03	.0419
CA-PSV (cm/s)	11.21 ± 5.36	9.24 ± 2.74	.1623	10.36 ± 4.92	9.77 ± 2.81	.7876
CA-PI	1.11 ± 0.19	0.90 ± 0.15	.0006	1.01 ± 0.19	0.92 ± 0.13	.3214
CA-RI	0.60 ± 0.08	0.54 ± 0.07	.0188	0.60 ± 0.08	0.55 ± 0.07	.2371
ITA-PSV (cm/s)	7.17 ± 1.46	6.60 ± 1.09	.1811	7.09 ± 1.33	6.77 ± 1.23	.6486
ITA-PI	0.96 ± 0.15	0.70 ± 0.16	< .0001	0.91 ± 0.15	0.76 ± 0.10	.0480
ITA-RI	0.57 ± 0.09	0.51 ± 0.06	.0208	0.54 ± 0.09	0.51 ± 0.05	.4557

Abbreviations: TMSC, total motile sperm counts; CDFI, Color Doppler Flow Imaging; EDV, end diastolic velocity; PI, pulsatility index; PSV, peak systolic velocity; RI, resistive index; CA, capsular artery; ITA, intratesticular artery.

ipsilateral CA and ITA were accordingly unchanged ($P > .05$). In both subgroup, the values of PSV of CA and ITA were insignificantly decreased ($P > .05$).

DISCUSSION

Varicocele is a commonly encountered disease in urology clinic. Doppler is not only helpful for the diagnosis of varicocele, but also can monitor the changes of testicular blood flow parameters before and after varicocelectomy.[10-12,14,16,17] The arteriovenous system of the testis is highly complex and under a fine regulation to maintain a proper spermatogenesis environment. The testicular, deferential and cremasteric arteries all provide the blood supply to the testis, and they form numerous anastomoses at the upstream of testicular parenchyma. At this point, they can not directly reflect testicular microcirculation but CA and ITA, which locate just in the capsule surface and deep parenchyma of the testis respectively, are more reliable. Normally pampiniform plexus can not only take away testicular metabolic waste but also play a role in cooling the arterial blood before it reaches the testis, helping ensure the organ stays at the proper temperature, yet the drainage and cooling function are impaired when varicocele arises. Varicocelectomy can partly restore the innate function of plexiform plexus in order to rectify the testicular microcirculation.[9,18]

Animal studies have shown indeterminate changes in testicular blood flow in association with varicocele. Li and colleagues demonstrated a decrease in testicular blood flow in rats after experimentally induced varicocele;[19] Ozturk and colleagues indicated that artificial varicocele induced by partial stenosis of the ipsilateral renal vein has no effect on testicular blood flow of both sides as determined by flow cytometry;[20] while others showed that testicular blood flow increased after the creation of experimental varicocele in dogs and rats and returned to baseline levels after varicocelectomy in rats.[21] This discrepancy may be partly explained by methodological differences in blood flow measurement and the durations of the created varicocele. Furthermore, experimentally induced varicocele models in animals are not completely identical to human, especially regarding different effects of gravity between human bipedalism and animal quadrupedalism.

Several clinical studies have investigated the effects of varicocele on testicular blood flow. Tarhan and colleagues reported that blood flow in varicocele bearing testicles is less abounded than normal control in men;[22] Akcar and colleagues reported that subclinical varicocele does not affect the intratesticular arterial RI,[14] and Ünsal and colleagues proved that increased RI and PI values of CA on spectral Doppler examination are indicators of impaired testicular microcirculation in patients with clinical varicocele.[17] Concerning varicocelectomy, Sun and colleagues used Doppler to investigate the changes in testicular perfusion following laparoscopic varicocele clipping in children and reported no significant change. However, they examined only the magnitude of arterial perfusion, and did not use any arterial flow parameters (PSV, EDV, RI, and PI) reflecting arterial flow hemodynamics.[23] Tanriverdi and colleagues compared microsurgery and high ligation varicocelectomy by evaluating intratesticular arterial flow by CDFI seven days after surgery, and reported no statistically difference between the preoperative and postoperative RI values in both groups.[16] A similar study comparing two laparoscopic surgical methods at 3 months follow-up demonstrated that mean RI value in the group of patients with spermatic artery ligation was comparable to the group of spermatic artery preservation.[24] Most importantly, Balci and colleagues first evaluated the long term effects of varicocelectomy on testicular blood flow. In their research, 26 infertile patients with left varicocele were operated and monitored up to the sixth month after the operation, though only ITA was evaluated and the microsurgical varicocelectomy technique was not applied. They found that the mean EDV value was increased, the RI and PI values were decreased, and the PSV value was unchanged after surgery.[12] Three years after Balci's study, Tarhan and colleagues observed the effects of microsurgical inguinal varicocelectomy (not MV) on testicular blood flow.[10] Their results showed that within six months after surgery the mean PSV and EDV of left TA increased, and RI and PI values of left CA and ITA decreased. No significant difference was detected between the preoperative and postoperative blood flow parameters in the right TA, CA and ITA. They believed that PSV and EDV values showed flow velocity; RI and PI values showed resistance against blood flow, so they assumed that the blood flow into the ipsilateral testis increased and the resistance against blood flow in affected testis decreased after surgery. Therefore they concluded that the PSV and EDV values increase in TA and the PI and RI values decrease in CA and ITA, and they were the indicators of an increase in testicular arterial blood flow into the testicular tissue.

Our study is a prospective case-controlled cohort study, and initially intended to investigate the long term changes on the testicular microcirculation before and after laparoscopic varicocelectomy using CDFI in adults, however, surgical techniques evolve over time, subsequently an added purpose was to compare the two surgical techniques. For the first purpose, we found from the our results that the values of RI, PI and PSV in the left ITA and CA decreased within six months after surgery, which was similar to Tarhan's report.[10] Smaller RI and PI values reflect that arterial resistance of ipsilateral testis decreases after surgery, and smaller PSV values does not simply mean ipsilateral testicular blood supply decrease, but should be a self-regulation of preload due to the lighten afterload. As hemodynamic changes involving the capillary bed and/or venous drainage have direct effects on arterial impedance,[25] we infer that hydrostatic pressure (afterload) of affected testicular venous column decrease after pampiniform plexus is cleared.[10,12,17] The self-regulation must be gradually completed over PODs, so we have reason to believe that PSV and EDV values of CA and ITA would increase at the early postoperative period (within POD7 or POD30?) , then more such data are need in future. For the second purpose, our case-matched data demonstrate that MV is superior to LV based upon our limited CDFI data. The superiority is not caused by the learning curve though MV is performed posterior to LV as the surgeon (ZL) has passed the learning curve (> 20 years experiences), but mainly due to the surgical techniques. We suppose that the application of magnification make the microanatomy of spermatic cord sharper, and the high-definition operative field is positive to a better postoperative outcome. The microsurgical technique (inguinal or subinguinal) is an innovative technique that allows the ligation of all of the veins except the vasal vein while sparing the local arteries and lymphatics, and is proved to reduce the recurrence rate and complications.(26) The subinguinal approach (MV) does not incise the external oblique aponeurosis, reducing pain for the patient, but at the expense of the increased number of veins that must be ligated.(7) As such, MV is considered the gold-standard technique for varicocelectomy in adults.

Semen evaluation is not a principle index in our study, and infertility is neither our target illness, because merely less than half participants accepted this test. In the present study, only semen samples on two time points were collected, so correlation analysis between semen and CDFI parameters can not be quantified. Moreover, if we divide such handful of patients into four subgroups according to the surgical approaches multiply by semen improvement, the numbers of individual subgroups will be too small, thus meaningless for further statistical analyses. These are all limitations of our study. Even though, we can develop the trend that semen parameters are improved after varicocelectomy (LV or MV), which is in agreement with the majority of previous reports.(2,3,10,12) Besides, the values of PI and RI of ipsilateral CA or ITA seem negative correlated with sperm quality, which is also in accord with others.(10-12) Although the majority of patients achieved an improved TMSC, no couple achieved spontaneous pregnancy within the follow-up in either group, which is possibly because of the limited patient number and relatively short observation interval. Additionally, the maximal improvements in the CDFI parameters appeared as early as the 3rd month in MV group, while on the 6th month in LV group. This finding can partly explain Al Bakri's report that the sperm quality improves by 3 months after MV and then does not improve further.(27) As logically, if couples plan to receive intrauterine insemination or in vitro fertilization/intracytoplasmic sperm injection after correcting the male factor infertility associated with a varicocele, the efficient surgical approach for varicocele repair is MV rather than LV.

CONCLUSION

In conclusion, varicocelectomy (either LV or MV) results in a significant decrease in the values of PSV, PI, or RI of ipsilateral ITA or CA, and an improvement in semen parameters in left clinical varicocele patients, which suggests an improvement of the testicular blood supply or sperm quality. The values of RI and PI of ITA and CA will be two important indexes for the prognosis after varicocelectomy. MV has advantage to LV on postoperative CDFI parameters, and the former can advance an early and a more obvious promotion than the latter. Because the present study covered only a 6-month follow-up period, further studies in larger series, longer periods and with more time points are needed to test the relationship between testicular perfusion and sperm parameters after different varicocelectomy approaches.

ACKNOWLEDGEMENTS

This study is granted by the Postgraduate Research Fund of Qingdao University belonging to Professor Shibao Fang, Department of Ultrasound, Affiliated Hospital of Qingdao University and the author (MZ).

CONFLICTS OF INTEREST

None declared.

REFERENCES

1. Cimador M, Castagnetti M, Gattuccio I, Pensabene M, Sergio M, De Grazia E. The hemodynamic approach to evaluating adolescent varicocele. Nat Rev Urol. 2012;9:247-57.
2. Pasqualotto F, Borges E, Roth F, Lara L, Pasqualotto E. Varicocele: To Fix or Not to Fix. In: Sabanegh ES, editor. Male Infertility: Humana Press; 2011. p. 65-79.
3. Schauer I, Madersbacher S, Jost R, Hubner WA, Imhof M. The impact of varicocelectomy on sp--erm parameters: a meta-analysis. J Urol. 2012;187:1540-7.
4. Agarwal A, Hamada A, Esteves SC. Insight into oxidative stress in varicocele-associated male infertility: part 1. Nat Rev Urol. 2012;9:678-90.
5. Hamada A, Esteves SC, Agarwal A. Insight into oxidative stress in varicocele-associated male infertility: part 2. Nat Rev Urol. 2013;10:26-37.
6. Smit M, Romijn JC, Wildhagen MF, Veldhoven JL, Weber RF, Dohle GR. Decreased sperm DNA fragmentation after surgical varicocelectomy is associated with increased pregnancy rate. J Urol. 2013;189:S146-50.
7. Choi WS, Kim SW. Current issues in varicocele management: a review. World J Mens Health. 2013;31:12-20.
8. Hsiao W, Rosoff JS, Pale JR, Powell JL, Goldstein M. Varicocelectomy is associated with increases in serum testosterone independent of clinical grade. Urology. 2013;81:1213-7.
9. Reyes JG, Farias JG, Henriquez-Olavarrieta S, et al. The hypoxic testicle: physiology and pathophysiology. Oxid Med Cell Longev. 2012;2012:929285.
10. Tarhan S, Ucer O, Sahin MO, Gumus B. Longterm effect of microsurgical inguinal varicocelectomy on testicular blood flow. J Androl. 2011;32:33-9.
11. Pinggera GM, Mitterberger M, Bartsch G, et al. Assessment of the intratesticular resistive index by colour Doppler ultrasonography measurements as a predictor of spermatogenesis. BJU Int. 2008;101:722-6.
12. Balci A, Karazincir S, Gorur S, Sumbas H, Egilmez E, Inandi T. Long-term effect of varicocele repair on intratesticular arterial resistance index. J Clin Ultrasound. 2008;36:148-52.
13. Chiou RK, Anderson JC, Wobig RK, et al. Color Doppler ultrasound criteria to diagnose varicoceles: correlation of a new scoring system with physical examination. Urology. 1997;50:953-6.
14. Akcar N, Turgut M, Adapinar B, Ozkan IR. Intratesticular arterial resistance and testicular

volume in infertile men with subclinical varicocele. J Clin Ultrasound. 2004;32:389-93.
15. Lu WH, Gu YQ. Insights into semen analysis: a Chinese perspective on the fifth edition of the WHO laboratory manual for the examination and processing of human semen. Asian J Androl. 2010;12:605-6.
16. Tanriverdi O, Miroglu C, Horasanli K, Altay B, Caliskan KC, Gumus E. Testicular blood flow measurements and mean resistive index values after microsurgical and high ligation varicocelectomy. Urology. 2006;67:1262-5.
17. Unsal A, Turgut AT, Taskin F, Kosar U, Kara man CZ. Resistance and pulsatility index increase in capsular branches of testicular artery: indicator of impaired testicular microcirculation in varicocele? J Clin Ultrasound. 2007;35:191-5.
18. Kroese AC, de Lange NM, Collins JA, Evers JL. Varicocele surgery, new evidence. Hum Reprod Update. 2013;19:317.
19. Li H, Dubocq F, Jiang Y, Tiguert R, Gheiler EL, Dhabuwala CB. Effect of surgically induced varicocele on testicular blood flow and Sertoli cell function. Urology. 1999;53:1258-62.
20. Ozturk H, Surer I, Okur H, Demirbag S, Cetinkursun S. Testicular blood flow alterations and flow cytometric analysis in prepubertal rats with experimentally induced unilateral varicoc--ele. Eur Surg Res. 2003;35:98-102.
21. Turner TT. The study of varicocele through the use of animal models. Hum Reprod Update. 2001;7:78-84.
22. Tarhan S, Gumus B, Gunduz I, Ayyildiz V, Goktan C. Effect of varicocele on testicular artery blood flow in men--color Doppler investigation. Scand J Urol Nephrol. 2003;37:38-42.
23. Sun N, Cheung TT, Khong PL, Chan KL, Tam PK. Varicocele: Laparoscopic clipping and color Doppler follow-up. J Pediatr Surg. 2001;36:1704-7.
24. Student V, Zatura F, Scheinar J, Vrtal R, Vrana J. Testicle hemodynamics in patients after laparoscopic varicocelectomy evaluated using color Doppler sonography. Eur Urol. 1998;33:91-3.
25. Nelson TR, Pretorius DH. The Doppler signal: where does it come from and what does it mean? AJR Am J Roentgenol. 1988;151:439-47.
26. Mehta A, Goldstein M. Microsurgical varicocelectomy: a review. Asian J Androl. 2013;15:56-60.
27. Al Bakri A, Lo K, Grober E, Cassidy D, Cardoso JP, Jarvi K. Time for improvement in semen parameters after varicocelectomy. J Urol. 2012;187:227-31.