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Research Article

Microsurgical Varicocelectomy: Experience of Our Sub-Subinguinal Approach and Review of the Literature

Hanchao Liu,[1,2] Rui Chen,[1] Xiaolong Wu,[2] Mingxiao Zhang,[3] Zhengzheng Li,[2] Lin Hua,[2] Junfeng Zhan,[2] Biao Dong,[1] Zhenqing Wang,[4] Zhuolun Sun,[4] Xiaotao Li,[1] Jiaqin Liu,[1] Xiaodong Wang,[1] Ming Shen,[1] Chong Xie,[2] and Zhuanxin Jiang[1,2]

[1]*Department of Andrology, The Second Affiliated Hospital of Kunming Medical University, Kunming, Yunnan, China*
[2]*Department of Andrology and Urology, Sir Run Run Shaw Hospital, Affiliated with the Zhejiang University School of Medicine, Hangzhou, Zhejiang, China*
[3]*Department of Urology, China-Japan Friendship Hospital, Beijing, China*
[4]*Department of Urology, Shandong Provincial Hospital, Jinan, Shandong, China*

Correspondence should be addressed to Ming Shen; dr.shen.ming@qq.com, Chong Xie; philip_1981@hotmail.com and Zhuanxin Jiang; jiangzhuanxin@kmmu.edu.cn

Hanchao Liu, Rui Chen, and Xiaolong Wu contributed equally to this work.

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Objective. To discuss the experience with a novel surgical approach in the treatment of varicocele for fertility or pain in 772 patients. *Methods*. Retrospective analysis of 772 patients undergoing microsurgical sub-subinguinal (SSI) varicocelectomy in our hospital and the discussion of historical surgical approaches. *Results*. A total of 690 patients with left varicocele underwent surgical treatment for infertility ($n = 519$) and pain ($n = 171$). The sperm concentrations (mean ± standard deviation (SD)) of 519 patients measured preoperatively, 6 months postoperatively, and 12 months postoperatively were 19.24 ± 3.69 (10^6/ml), 27.42 ± 10.32 (10^6/ml), and 34.20 ± 16.29 (10^6/ml) ($^{**}P < 0.01$), respectively. The sperm motilities (mean ± SD) of 519 patients measured preoperatively, 6 months postoperatively, and 12 months postoperatively were 13.78 ± 3.25, 20.98 ± 8.21, and 27.59 ± 13.71 (grade (a + b) %) ($^{**}P < 0.01$), respectively. Pain was released surgically in 131 (76.6%) of the 171 patients. A total of 82 patients with bilateral varicocele underwent surgical treatment for infertility ($n = 58$) and pain ($n = 24$). The sperm concentrations (mean ± SD) of 58 patients measured preoperatively, 6 months postoperatively, and 12 months postoperatively were 19.21 ± 3.24 (10^6/ml), 27.36 ± 10.26 (10^6/ml), and 33.87 ± 15.20 (10^6/ml) ($^{**}P < 0.01$), respectively. The sperm motilities (mean ± SD) of 58 patients measured preoperatively, 6 months postoperatively, and 12 months postoperatively were 13.54 ± 2.75, 20.75 ± 8.21, and 28.53 ± 14.83 (grade (a + b) %) ($^{**}P < 0.01$), respectively. Pain was released surgically in 19 (79.2%) of the 24 patients. The probability of occurrence in one artery, two arteries, three arteries, and more than three arteries was 29.5%, 28.8%, 19.9%, and 1.9%, respectively. *Conclusion*. This surgical approach achieves a small and esthetic skin wound with fewer complications. The SSI approach is a safe and widely adopted surgical approach option for the treatment of varicocele.

1. Introduction

The prevalence of varicocele is approximately 10%–15% in the adult male population; approximately 35% of cases are associated with infertility, and 10% of cases are associated with testicular pain [1]. Surgical solutions for infertility or pain caused by varicocele have been widely promoted by doctors and guidelines worldwide [1]. The surgical treatment options for varicocele are numerous, including open ligation [2, 3], laparoscopic high ligation [4, 5], microsurgical varicocelectomy (MV) [6, 7], and embolization of the spermatic vein [8, 9].

MV is superior for identifying and protecting the testicular arteries and lymphatic vessels by magnifying the contents of the spermatic cord through a surgical microscope. MV is

also useful for identifying small spermatic veins for ligation; this greatly reduces surgical complications and postoperative recurrence rates and has led to MV being recognized as the gold standard surgical procedure for varicocele. MV has been performed in our hospitals following study of the procedure by Goldstein et al. [6].

Here, our hospitals started to perform MV by using a subsubinguinal (SSI) surgical approach in 2014 with continuous review of the operation due to the increasing demand for enhanced esthetics by many patients. From February 2014 to August 2020, we performed approximately 1,400 MV operations using our novel SSI approach in the Department of Andrology or Urology in several hospitals. A total of 772 patients with complete follow-up data of varicocele were included in this study. Herein, the experience and data of this surgical approach are analyzed and discussed.

2. Methods

2.1. Patient Characteristics. The 772 patients included in this study were aged between 20 and 50 years old, and all patients had a color Doppler ultrasound performed (diameter of the internal spermatic vein greater than 3 mm and/or venous reflux greater than 4 s), imaging grade III. Varicoceles were diagnosed by physical examination and were grade 2 or 3. All of the patients had symptoms of male infertility (primary infertility for more than 1 year, abnormal sperm concentration and motility [10], normal gynecologic assessment in the patient's partner) or unbearable pain; all patients had no significant abnormalities in the preoperative sex hormone panel, and the volume of each testis was >12 ml. Secondary varicocele and other specific diseases causing intolerability of the surgical procedure were excluded. All patients included in this study had complete follow-up information, and the study was approved by the Ethics Committee of Sir Run Run Shaw Hospital, Zhejiang University School of Medicine (Approval NO.: 2022-0406).

2.2. Surgical Procedures, Perioperative Management, and Follow-Up Information. The surgical protocol is shown in Figure 1(a) (steps (1) to (6)). All procedures were performed by or under the supervision of MD. Jiang, MD. Shen, and MD. Xie. First, two fingers were used to identify the spermatic cord at the point where it travels under the skin, and a small knife was used to make an incision on the skin surface in the direction of the skin texture (1–1.5 cm). The subcutaneous tissue and superficial fascia were bluntly separated to expose the spermatic cord, and this was grasped with curved forceps. The spermatic cord was picked up with a 14 Fr drainage tube, and the external fascia of the spermatic cord was opened to expose the contents of the spermatic cord. Then, the vas deferens plexus was separated and isolated with a 14 Fr drainage tube, with care taken to protect the vas deferens artery. The internal spermatic veins were separated and ligated layer by layer under a microscope, and the lymphatics and arteries were protected. After ligation of the internal spermatic veins, the entire spermatic cord was observed. Then, the thick (>3 mm) external spermatic veins and vas deferens veins were also ligated. Finally, the outer sheath of the spermatic cord was closed, the spermatic cord was retracted, and the incision was closed in sequence.

Postoperative treatment and follow-up: after surgery, small towels were used to support the scrotum and testicles, and the patients rested in bed for 8–12 hr. The patient was allowed to ambulate and leave the hospital at 8–12 hr after surgery. Follow-up was performed 7–15 days after surgery to observe wound recovery. At 6 and 12 months after surgery, complications, such as hydrocele, recurrence, and testicular atrophy, were monitored; additionally, sperm concentration and motility were checked.

2.3. Statistical Analysis. The classification of patients included in our retrospective study is shown in Figure 2. Quantitative variables are expressed as the mean ± standard deviation (SD). An analysis of variance shows the differences between the three groups of data. If the result yielded a value of $P<0.05$, Fisher's least significant difference was used to further analyze whether there were significant differences between the two groups. Statistical analysis was carried out with the statistical software SPSS 22.0, and the levels of significance were $^{*}P<0.05$ and $^{**}P<0.01$.

3. Result

3.1. Results of Surgery for Infertility in Left Varicocele Patients. A total of 690 patients included in this study had left varicocele; among these patients, 519 were treated for infertility (Figure 2). The sperm concentrations (mean ± SD) of 519 patients measured preoperatively, 6 months postoperatively, and 12 months postoperatively were 19.24 ± 3.69 (10^6/ml), 27.42 ± 10.32 (10^6/ml), and 34.20 ± 16.29 (10^6/ml) ($^{**}P<0.01$), respectively. The sperm motilities (mean ± SD) of 519 patients measured preoperatively, 6 months postoperatively, and 12 months postoperatively were 13.78 ± 3.25, 20.98 ± 8.21, and 27.59 ± 13.71 (grade (a + b) %) ($^{**}P<0.01$), respectively. The results are shown in Table 1. Among the 519 patients treated for infertility, 327 patients showed significant improvement in sperm quality. The sperm concentrations (mean ± SD) of these 327 patients measured preoperatively, 6 months postoperatively, and 12 months postoperatively were 19.23 ± 3.42 (10^6/ml), 34.52 ± 5.13 (10^6/ml), and 45.75 ± 7.54 (10^6/ml); the mean sperm viability grade (a + b) percentage measured preoperatively, 6 months postoperatively and 12 months postoperatively was 13.43 ± 3.64, 26.23 ± 5.54, and 37.27 ± 6.59, respectively. The results are shown in Table 2.

3.2. Results of Surgery for Pain in Left Varicocele Patients. A total of 171 patients were treated for pain (mean age: 28.4 ± 4.2); the pain disappeared in 131 patients as a result of surgery, with a pain relief rate of 76.6%.

3.3. Results of Surgery for Infertility in Bilateral Varicocele Patients. A total of 82 patients included in this study had bilateral varicocele; among these patients, 58 patients were treated for infertility (Figure 2). The sperm concentrations (mean ± SD) of 82 patients measured preoperatively, 6 months postoperatively, and 12 months postoperatively were 19.21 ± 3.24 (10^6/ml), 27.36 ± 10.26 (10^6/ml), and

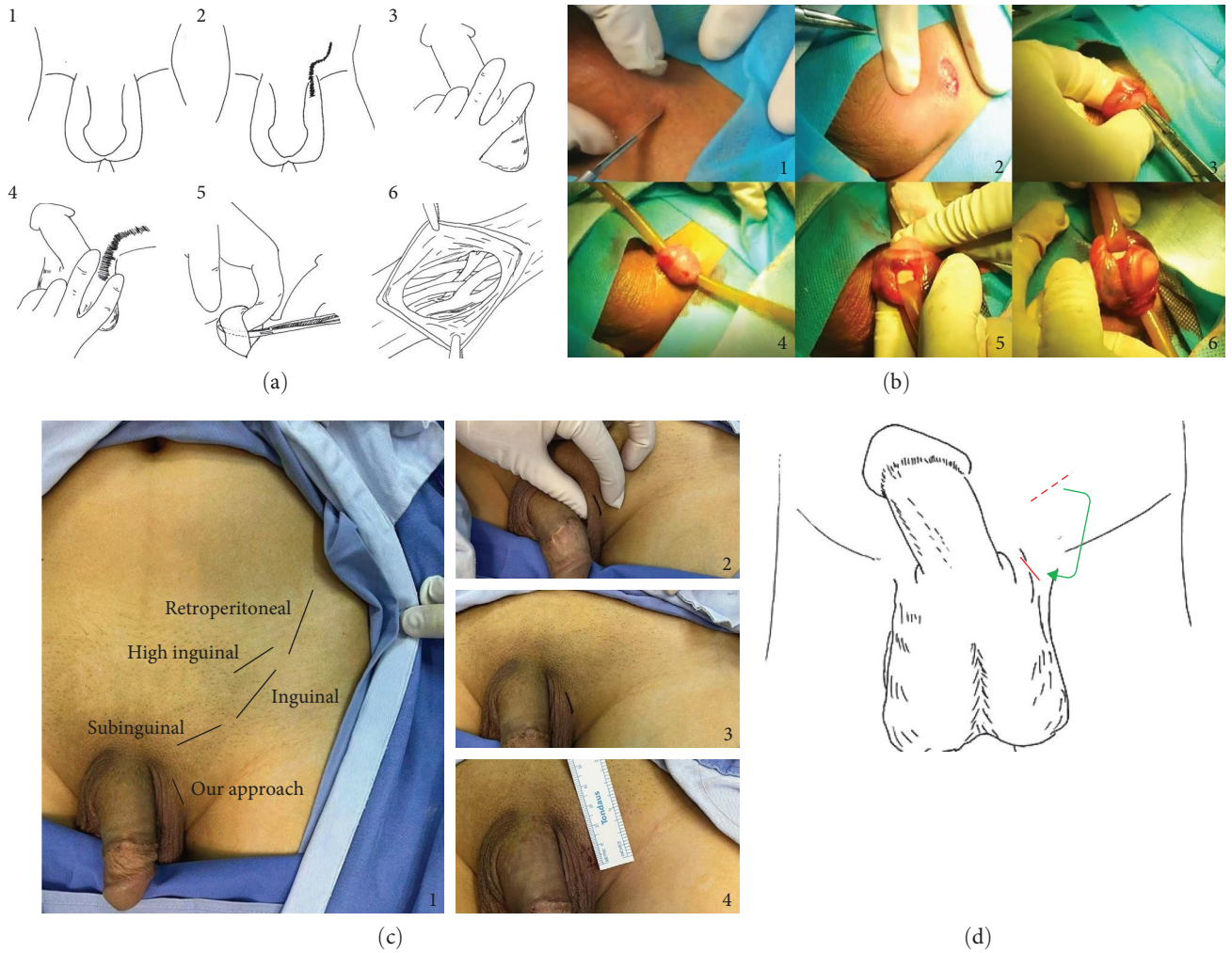

Figure 1: Schematic diagram of the surgical approach. (a) SSI approach diagram. (1) Appearance of the male perineum and lower abdomen. (2) Projection of the spermatic cord on the body surface. (3) Two fingers perceive the outline of the spermatic cord at the junction of the scrotum and lower abdominal skin. (4) Position the incision above the spermatic cord. (5) The skin was cut, the superficial fascia was separated, and the spermatic cord was lifted with curved forceps. (6) The method of separating the external fascia of the spermatic cord was consistent with that of microsurgical subinguinal varicocelectomy. (b) SSI approach during the operation. (1) Two fingers sense the spermatic cord alignment to determine the incision location. (2) The size of the incision is approximately 1–1.5 cm. (3) The spermatic cord is lifted with forceps. (4) The sensory cord was raised with a 14 Fr drainage tube. (5) The external fascia of the spermatic cord is separated, and then the vas deferens is exposed. (6) The vas deferens is protected by compression with another 14 Fr drainage tube. (c) (1) Surgical approaches in MV. (2)–(4) Our approach before and after operation. (d) Comparison of our surgical approach with subinguinal approach.

33.87 ± 15.20 (10^6/ml) ($^{**}P < 0.01$), respectively. The sperm motilities (mean $\pm$ SD) of 519 patients measured preoperatively, 6 months postoperatively, and 12 months postoperatively were 13.54 ± 2.75, 20.75 ± 8.21, and 28.53 ± 14.83 (grade (a + b)) ($^{**}P < 0.01$), respectively. The results are shown in Table 2. Of the 58 patients with infertility, 38 patients showed significant improvement in sperm quality. The sperm concentrations (mean $\pm$ SD) of these 38 patients measured preoperatively, 6 months postoperatively, and 12 months postoperatively were 19.26 ± 3.12 (10^6/ml); 33.76 ± 6.12 (10^6/ml); 43.56 ± 8.55 (10^6/ml); the mean sperm viability grade (a + b) percentage measured preoperatively, 6 months postoperatively, and 12 months postoperatively was 13.24 ± 3.17, 25.35 ± 6.14, 38.23 ± 7.65. The results are shown in Table 2.

3.4. Results of Surgery for Pain in Left Varicocele Patients. A total of 24 patients were treated for pain (mean age: 28.3 ± 5.5); pain disappeared in 19 patients as a result of surgery, with a pain relief rate of 79.2%.

3.5. Complications. The complications of left varicocelectomy (Table 1) were as follows: recurrence of varicocele 3/690 (0.43%), fat liquefaction 3/690 (0.43%), incision infection 1/690 (0.14%), testicular atrophy 0/690, epididymitis 0/690, scrotal hematoma 5/690 (0.72%), hydrocele 0/690, edema (7 days) 55/690 (7.97%), and edema (14 days) 0/690.

The complications of bilateral varicocelectomy (Table 1) were as follows: recurrence of varicocele 1/164 (0.61%), fat liquefaction 0/164, wound infection 0/164, testicular atrophy 0/164, epididymitis 0/164, scrotal hematoma 1/82 (1.22%),

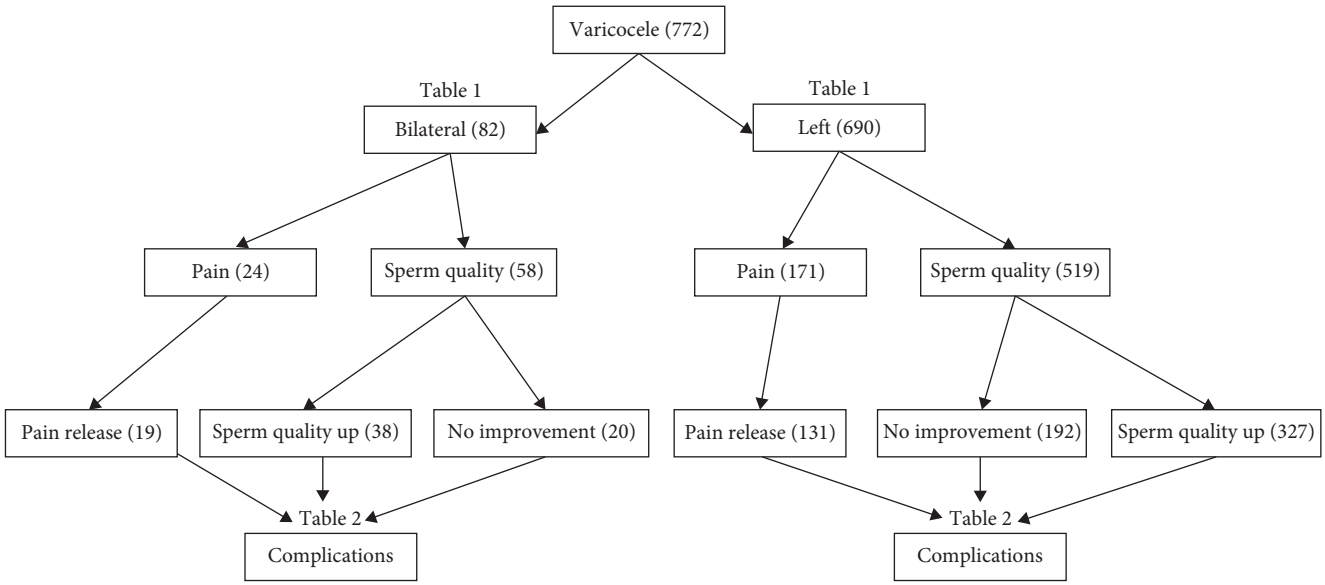

Figure 2: Study sample grouping diagram.

Table 1: Adverse effects of our varicocele surgery.

	Number of occurrences/total number of operations (left)	Number of occurrences/total number of operations (left + right = 164)
Recurrence of varicocele	3/690	1/164
Fat liquefaction	3/690	0/164
Incision infection	1/690	0/164
Testicular atrophy	0/690	0/164
Epididymitis	0/690	0/164
Scrotal hematoma	5/690	1/82
Hydrocele	0/690	0/164
Edema (7 days)	55/690	15/82
Edema (14 days)	0/690	0/82

Table 2: Semen indexes of left varicocele patients with low sperm quality.

	Age (mean ± SD)	Preoperation (mean ± SD)	6 months after surgery (mean ± SD)	12 months after surgery (mean ± SD)
Left varicocele patients				
All operated patients (519)	27.4 ± 4.6			
Sperm concentration × 10^6/ml		19.24 ± 3.69	27.42 ± 10.32[a]	34.20 ± 16.29[b,c]
Grade (a + b) %		13.78 ± 3.25	20.98 ± 8.21[a]	27.59 ± 13.71[b,c]
Patient with improved sperm quality (327/519)				
Sperm concentration × 10^6/ml		19.23 ± 3.42	34.52 ± 5.13	45.75 ± 7.54
Grade (a + b) %		13.43 ± 3.64	26.23 ± 5.54	37.27 ± 6.59
Bilateral varicocele patients				
All operated patients (58)	27.1 ± 4.8			
Sperm concentration × 10^6/ml		19.21 ± 3.24	27.36 ± 10.26[a]	33.87 ± 15.20[b,c]
Grade (a + b) %		13.54 ± 2.75	20.75 ± 8.21[a]	28.53 ± 14.83[b,c]
Patient with improved sperm quality (38/58)				
Sperm concentration × 10^6/ml		19.26 ± 3.12	33.76 ± 6.12	43.56 ± 8.55
Grade (a + b) %		13.24 ± 3.17	25.35 ± 6.14	38.23 ± 7.65

[a]**6 months after surgery vs. preoperation ($P < 0.01$). [b]**12 months after surgery vs. preoperation ($P < 0.01$). [c]**6 months after surgery vs. 6 months after surgery ($P < 0.01$).

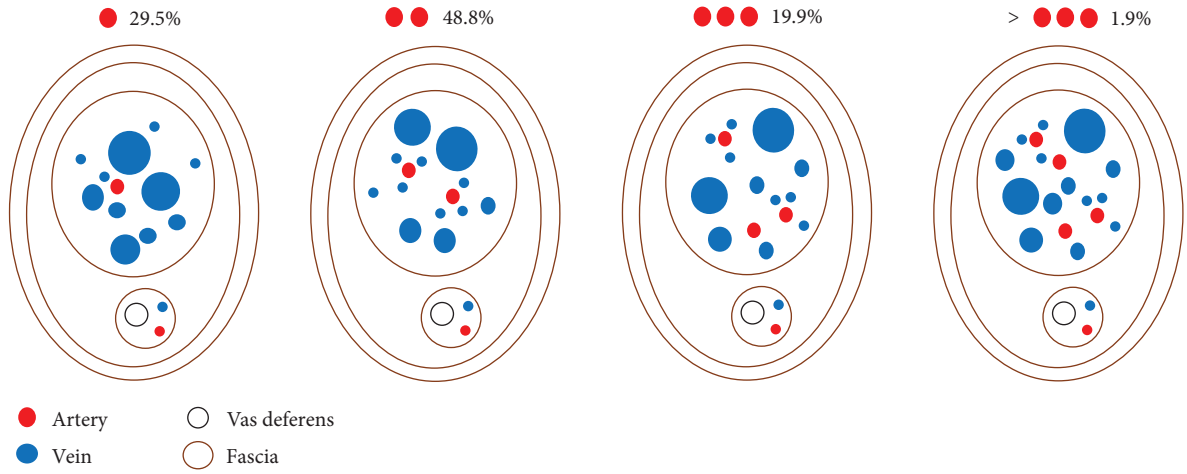

Figure 3: Map of artery distribution.

hydrocele 0/164, edema (7 days) 15/82 (18.29%), and edema (14 days) 0/82.

3.6. Number of Arteries. According to our intraoperative statistics, the probability of occurrence in one artery, two arteries, three arteries, and three or more arteries was 29.5%, 28.8%, 19.9%, and 1.9%, respectively (Figure 3).

4. Discussion

Varicocele has been known to trouble men's physical and mental health for a long time, and the development of surgical methods has spanned almost a century. Herein, we summarize the history of classical surgical methods and complications of varicocelectomy (Table 3). In the 1920s, Ivanissevich [3] started to perform varicocele ligation with an open inguinal approach and achieved good results. In 1947, Palomo [2] introduced open high ligation of varicocelectomy with a retroperitoneal approach and provided the details of the surgical protocol, which has been widely adopted with good results. From 1982 to 1992, Ross and Ruppman [11] concluded that open inguinal varicocelectomy has good efficacy; however, the recurrence rate of open surgery is high from today's perspective.

In the 1990s, with the explosion of technology, advanced interventional, microscopic, and laparoscopic equipment were introduced to the clinical setting. In 1992, Mehan et al. [4] demonstrated laparoscopic high ligation of the spermatic vein with the help of laparoscopy. This surgical option greatly reduced the operative time, especially in the management of bilateral varicocele. However, complications associated with laparoscopy also arose, such as scrotal emphysema, shoulder pain, and other laparoscopy-related complications. In the following 2 years, Jarow et al. [12], Ralph et al. [13], and Enquist et al. [14] used laparoscopic surgery for the treatment of varicocele; despite less surgical bleeding and decreases in wound infection rates, the recurrence rate and laparoscopy-related complications remained high. Yavetz et al. [9] treated varicocele by embolization; however, a high probability of recurrence still existed. Meanwhile, Tauber and Johnsen [8] found that embolization also had a high probability of surgery failure. In 1992, Goldstein et al. [6] introduced microscopic subinguinal varicocelectomy, a more minimally invasive and accurate surgical method. By ligating all veins one by one under the microscope and preserving the lymphatics and arteries, the patient had a better prognosis and fewer complications. In 1993, Ito et al. [15] and in 1994, Marmar and Kim [7] also adopted microscopic subinguinal varicocelectomy with sparing lymphatics and arteries. They reported more precision ligation, a high success rate and fewer complications. Thus, the four basic surgical concepts of surgical treatment of varicocele, namely, open surgery, microscopic varicocelectomy, embolization of varicocele and laparoscopic varicocelectomy, were established.

In the following 30 years, almost all the surgical treatments of varicocele around the world have originated from these four concepts. In 1996, Mandressi et al. [5] used a two-port laparoscope for high ligation of varicocele and found that the incision was less likely to be infected and necrotic than in open surgery. Indeed, the vertical puncture channel caused less damage to the blood supply of subcutaneous fat and did not easily lead to fat liquefaction and wound infection. Additionally, laparoscopic surgery for bilateral varicocele had a unique speed advantage. However, previous studies have indicated that laparoscopic surgery leads to a high recurrence rate and a high probability of postoperative complications, including hydrocele and the unavoidable laparoscopic complications, which are disadvantageous; however, the laparoscopic surgical method benefits from a short operation time and fewer wound infections [16–23]. Simforoosh et al. [24] found that laparoscopic outcomes and complications were similar to those of traditional open ligation of varicocele. Zampieri et al. [25] reported laparoscopic varicocelectomy with artery preservation. However, it was found that this procedure leads to a high recurrence rate due to the high probability of missing tiny veins. In 2016, Lv et al. [21] reported that the probability of testicular atrophy in laparoscopic varicocelectomy was also higher than that in other surgical options. Perhaps this type of surgical option is preferred by urologists who are accustomed to laparoscopic surgery.

Table 3: Surgical approaches and their complications for varicocele in researches.

Researchers	Year	Cases	Approach	Incision length (cm)	Complications (*n*)
Palomo [2]	1947	36 (left) 2 (bilateral)	Retroperitoneal	3–4	No surgical accident or complication report
Ross and Ruppman [12]	1982/1993	488 (left) 75 (bilateral) 2 (right)	Internal inguinal ring	2–3	Hematomas (2) Hydrocele (41)
Goldstein et al. [6]	1992	218 (left) 211 (bilateral)	Microsurgical subinguinal	2–3	Hematomas (4) Recurrences (4) Hydrocele (0) Atrophy (0) Wound infections (0)
Mehan et al. [4]	1992	51 (bilateral)	Laparoscopic surgery	3 ports (10 mm, 10 mm, 5 mm trocar)	Hydrocele (2) Shoulder pain (3) Ecchymosis (1) Scrotal emphysema (1)
Yavetz et al. [9]	1992	51 (left)	Embolization of the spermatic vein	Percutaneous	Recurrences (12)
		43	High ligation (Ivanissevich)	3–4	Recurrences (16)
		43	High ligation (Bernardi)	3–4	Recurrences (15)
lto et al. [15]	1993	56 (left)	Microsurgical subinguinal	2–3	Hydroceles (1) Recurrences (2) Edema (7)
Jarow et al. [12]	1993	46	Laparoscopic surgery	3 ports (10, 10, 5 mm trocar)	Bleed (1) Recurrences (1)
Ralph et al. [13]	1993	49	Laparoscopic surgery	3 ports (10, 10, 5 mm trocar)	Recurrences (7) Wound infection (4) Hematomas (1) Vasal injury (1)
Enquist et al. [14]	1994	4 (left) 10 (bilateral)	Laparoscopic surgery	3 ports (10, 10, 5 mm trocar)	Recurrences (1)
		10 (left) 23 (bilateral)	Microsurgical subinguinal	2–3	Recurrences (0)
Tauber and Johnsen [8]	1994	253 (unilateral) 32 (bilateral)	Antegrade scrotal sclerotherapy	Percutaneous	Failed surgery (57)
Marmar and Kim [7]	1994	326 (left) 140 (bilateral)	Microsurgical subinguinal	2–3	Hydroceles (4) Ecchymosis (16) Suture reaction (11) Epididymal discomfort (26) Recurrences (10) Atrophy (0)
Miersch et al. [17]	1995	44 (left) 7 (bilateral)	Laparoscopic surgery	3 ports (10, 10, 5 mm trocar)	Bleed (1) Shoulder pain (8)
Tan et al. [16]	1995	72 (left) 26 (bilateral)	Laparoscopic surgery	3 ports (10, 10, 5 mm trocar)	Pneumoscrotum (2) Wound infection (2)
Milad et al. [22]	1996	48	Laparoscopic surgery	3 ports (10, 10, 5 mm trocar)	Hydroceles (3) Pain (1) Wound infection (1)

Table 3: Continued.

Researchers	Year	Cases	Approach	Incision length (cm)	Complications (*n*)
Mandressi et al. [5]	1996	160	Laparoscopic surgery	2 ports (10, 5 mm trocar)	Recurrences (5) Shoulder pain (1) Hydroceles (0) Wound infections (0)
		120	Open inguinal		Recurrences (8) Shoulder pain (0) Hydroceles (2) Wound infections (7)
Shlansky-Goldberg et al. [35]	1997	149	Open inguinal (Ivanissevich)	3	Recurrences (24) Failed surgery (1) Wound infections or hematomas (10)
		197	Percutaneous embolization	Percutaneous	Recurrences (8) Failed surgery (25) Wound infections or hematomas (22)
Cayan et al. [49]	2000	142 (left) 90 (bilateral)	Retroperitoneal	3–4	Recurrences (36) Hydrocele (5)
		128 (left) 108 (bilateral)	Microsurgical high inguinal	2–3	Recurrences (12) Hydrocele (1)
Testini et al. [39]	2001	150	Microsurgical subinguinal	2–3	Pain (7) Ecchymosis (3) Hydroceles (2) Recurrences (5)
Jungwirth et al. [40]	2001	235 (unilateral) 37 (bilateral)	Microsurgical subinguinal	3–4	Hydrocele (1) Recurrences (4) Hematomas (1) Wound infection (4)
Kumar and Gupta [47]	2003	36 (unilateral) 54 (bilateral)	Microsurgical subinguinal	2–3	Recurrences (1) Hydrocele (3) Hematomas (2) Ecchymosis (1) Wound infection (8) Hydrocele (3) Atrophy (0)
Ghanem et al. [41]	2004	210 (left) 94 (bilateral)	Subinguinal Microsurgical	2–3	Recurrences (0) Hydrocele (5)
		77 (left) 32 (bilateral)	Retroperitoneal	3–4	Recurrences (8) Hydrocele (7)
Nabi et al. [29]	2004	50 (left) 15 (right) 6 (both)	Retrograde varicocele embolization	Percutaneous	Failed surgery (3) Recurrences (1)
Orhan et al. [50]	2005	68 (left) 14 (bilateral)	Microsurgical high inguinal	3–4	Recurrences (1) Wound infection (2)
		49 (left) 16 (bilateral)	Microsurgical subinguinal	2–3	Recurrences (2) Wound infection (1)

Table 3: Continued.

Researchers	Year	Cases	Approach	Incision length (cm)	Complications (*n*)
Zini et al. [42]	2005	101 (left) 64 (bilateral)	Microsurgical subinguinal	2–3	Recurrences (0) Hydroceles (0)
Watanabe et al. [18]	2005	47 (left) 3 (bilateral)	Retroperitoneal	3–4	Recurrences (6) Hydrocele (5)
		32 (left) 1 (bilateral)	Laparoscopic surgery	3 ports (10, 10, 5 mm trocar)	Recurrences (2) Emphysema (2) Hydrocele (1)
		60 (left) 1 (bilateral)	Microsurgical subinguinal	2–3	Recurrences (0)
Zucchi et al. [30]	2005	32 (left)	Open inguinal	4–5	Recurrences (2)
		32 (left)	Antegrade scrotal sclerotherapy	Percutaneous	Recurrences (3)
Al-Hunayan et al. [19]	2006	30	Two-trocar laparoscopic	Two ports (5, 5 mm)	Bleeding (1)
		30	Three-trocar laparoscopic	Three ports (5, 5, 5 mm)	Bleeding (2)
Al-Kandari et al. [20]	2007	28 (left) 12 (bilateral)	Open inguinal	3–4	Recurrences (7) Hydroceles (7)
		30 (left) 10 (bilateral)	Laparoscopic surgery	3 ports (10, 10, 5 mm trocar)	Recurrences (9) Hydroceles (10)
		35 (left) 5 (bilateral)	Microsurgical subinguinal	2–3	Recurrences (1) Hydroceles (0)
Simforoosh et al. [24]	2007	40 (left) 10 (bilateral)	Laparoscopic surgery	3 ports (10, 10, 5 mm trocar)	Recurrences (4) Hydroceles (7) Wound infection (0) Emphysema (8)
		44 (left) 6 (bilateral)	Open inguinal	3–4	Recurrences (2) Hydroceles (12) Wound infection (3) Emphysema (0)
Zampieri et al. [25]	2007	63	Laparoscopic (ligation)	3 ports (10, 10, 5 mm trocar)	Recurrences (0) Hydroceles (8)
		59	Laparoscopic (artery preserving)	3 ports (10, 10, 5 mm trocar)	Recurrences (5) Hydroceles (1)
Galfano et al. [31]	2008	605 (left) 85 (bilateral) 7 (right)	Antegrade scrotal sclerotherapy	Percutaneous	Failed surgery (63)
Gandini et al. [36]	2008	244	Transcatheter foam sclerotherapy	Intravenous	Allergic (1) Leakage (4) Fever (2) Recurrences (9)

Table 3: Continued.

Researchers	Year	Cases	Approach	Incision length (cm)	Complications (*n*)
		41 (left) 51 (bilateral)	Open inguinal	3–4	Recurrences (16) Hydroceles (4) Wound infection (2) Hematomas (2) Pain (4)
Al-Said et al. [48]	2008	40 (left) 54 (bilateral)	Laparoscopic surgery	3 ports (10, 10, 5 mm trocar)	Recurrences (25) Hydroceles (8) Wound infection (0) Hematomas (0) Pain (6)
		69 (left) 43 (bilateral)	Microsurgical subinguinal	2–3	Recurrences (4) Hydroceles (0) Wound infection (2) Hematomas (1) Pain (2)
		49 (left) 33 (bilateral)	Microsurgical subinguinal	2–3	Recurrences (0) Edema (2) Hydrocele (1) Wound infection (2) Atrophy (0)
Abdel-Maguid and Othman [43]	2010				
		46 (left) 33 (bilateral)	Open subinguinal	2–3	Recurrences (9) Edema (3) Hydrocele (7) Wound infection (2) Atrophy (2)
		22 (left) 33 (bilateral)	Open inguinal (Ivauissevich)	3–4	Recurrences (6) Fever (0) Hematomas (3) Wound infection (0) Hydrocele (3) Pain (4)
Fayez et al. [32]	2010	27 (left) 24 (bilateral)	Antegrade scrotal sclerotherapy	Percutaneous	Recurrences (9) Fever (3) Hematomas (5) Wound infection (1) Hydrocele (0) Pain (5)
		23 (left) 26 (bilateral)	Subinguinal Antegrade inguinal sclerotherapy	Percutaneous	Recurrences (4) Fever (2) Hematomas (0) Wound infection (1) Hydrocele (0) Pain (1)

Table 3: Continued.

Researchers	Year	Cases	Approach	Incision length (cm)	Complications (*n*)
Kim et al. [44]	2012	76 (unilateral) 5 (bilateral)	Microsurgical subinguinal	2–3	Recurrences (2) Hydrocele (0) Hematomas (1) Wound infection (1)
Shiraishi et al. [51]	2012	143 (left)	Microsurgical high inguinal	2.5–3	Recurrence (2) Hydrocele (1)
Söylemez et al. [45]	2012		Microscopic subinguinal	2–3	Wound infection (1) Hematomas (0) Atrophy (0) Orchitis (0) Edema (3) Hydrocele (1) Recurrences (1) Emphysema (0)
			Laparoscopic	3 ports (10, 10, 5 mm trocar)	Wound infection (0) Hematomas (0) Atrophy (0) Orchitis (1) Edema (1) Hydrocele (2) Recurrences (2) Emphysema (5)
Pan et al. [46]	2013	27 (unilateral) 32 (bilateral)	Microsurgical inguinal	3–4	Recurrence (3) Hydrocele (0)
		20 (unilateral) 36 (bilateral)	Microsurgical subinguinal	2–3	Recurrence (2) Hydrocele (1)
Crestani et al. [33]	2016	580 (left) 80 (bilateral) 14 (right)	Antegrade scrotal sclerotherapy	1–2	Failed surgery (4) Recurrences (40) Hematomas (12) Wound infection (9) Pain (21)
Lv et al. [21]	2016	60 (left) 24 (bilateral)	Laparoscopic surgery	3 ports (10, 10, 5 mm trocar)	Edema (8) Atrophy (7) Recurrence (10)
		71 (left) 24 (bilateral)	Microsurgical inguinal	3–5	Edema (3) Atrophy (5) Recurrence (3)
		68 (left) 18 (bilateral)	Microsurgical subinguinal	3–4	Edema (1) Atrophy (1) Recurrence (1)
		73 (left) 17 (bilateral)	Microsurgical retroperitoneal	3–4	Edema (2) Atrophy (4) Recurrence (2)

Table 3: Continued.

Researchers	Year	Cases	Approach	Incision length (cm)	Complications (*n*)
Shiraishi et al. [52]	2016	41	Microsurgical subinguinal	2–3	Recurrence (0) Hydrocele (1)
		40	Microsurgical high inguinal	2–3	Recurrences (0) Hydrocele (0)
Hosseini et al. [23]	2018	22	Laparoscopic surgery	3 ports (10, 10, 5 mm trocar)	Hematoma (1) Recurrences (5) Hydrocele (8) Pneumoscrotum (1) Pain (2)
		23	Open inguinal	3–4	Hematoma (4) Recurrences (2) Hydrocele (5) Pneumoscrotum (0) Pain (2)
		25	Retroperitoneal	3–4	Hematoma (1) Recurrences (0) Hydrocele (2) Pneumoscrotum (0) Pain (3)
McCullough et al. [26]	2018	258	Robotic-assisted Microsurgical subinguinal	2 (3 arms and 1 camera assisted)	Recurrences (25) Atrophy (0) Hydrocele (25) Hematoma (7)
Demirdöğen et al. [53]	2019	62	Microsurgical subinguinal	2–3	Recurrences (0) Atrophy (1) Hydrocele (1)
		74	Microsurgical internal inguinal	2–3	Recurrences (0) Atrophy (0) Hydrocele (0)
Teng et al. [27]	2020	45	Robotic-assisted laparoscopic varicocelectomy with g indocyanine green fluorescence angiography	3 ports (10, 10, 5 mm trocar)	Recurrences (0) Atrophy (0) Hydrocele (0)
Ouanes et al. [34]	2022	79	Open inguinal	3–4	Recurrences; hydrocele; orchitis; hematoma; wound infection (8)
		63	Antegrade sclerotherapy	Percutaneous	Recurrences; hydrocele; orchitis; hematoma; wound infection (7)
		65	Laparoscopic surgery	3 ports (10, 10, 5 mm trocar)	Recurrences; hydrocele; orchitis; hematoma; wound infection (6)

With the advent of robots, various types of surgeries assisted by robots are gradually emerging. In 2018, McCullough et al. [26] thought open surgery of the subinguinal approach assisted by robots has achieved good results. In 2020, Teng et al. [27] launched robotic-assisted laparoscopic artery-sparing varicocelectomy using indocyanine green fluorescence angiography achieved better arteries spare. Napolitano et al. [28] believed with the help of robots, a high-quality, 3D visualization and less tremor can contribute to the precision of surgery. However, the high cost of using robots must be taken into account.

At the same time, radiation therapy techniques were also used to seek solutions for varicocele. With the help of radiation equipment, vascular embolization or injection of sclerosing agents made the surgical incision smaller and more esthetic; however, they also led to a higher rate of surgical failure and recurrence [29–34]. In 1994, Tauber and Johnsen [8] reported 285 cases of antegrade scrotal sclerotherapy and 57 surgical failures out of 285 surgeries. In 1997, Shlansky-Goldberg et al. [35] reported 197 cases treated with percutaneous vascular embolization, of which 25 were surgical failures. In 2004, Nabi et al. [29] performed varicocele embolization in 71 patients, and three cases of failure were noted. In 2008, Galfano et al. [31] performed antegrade scrotal sclerotherapy on 800 patients with varicocele, and the surgical failure rate of the operation was nearly 10%. Compared with open inguinal or laparoscopic surgery, these methods have no advantages except for the esthetics of the skin incision after operation [32, 34, 36]. Other relevant studies have suggested that the new type of varicocele bypass vein anastomosis surgery is more aligned with human anatomy than venous embolism and can achieve etiological treatment [37]. However, it is still difficult to accurately judge the efficacy of bypass surgery and the standard of postoperative reexamination. At the same time, vein anastomosis surgery increases the chance of thrombosis and greatly prolongs the operation time; however, this is controversial [38]. A small percutaneous incision is more esthetic, and this is a factor that patients and doctors use to determine the optimal surgical option. Our research found that the size of our surgical incision was 1–1.5 cm, which is almost the same as that of embolization treatment. It is difficult to detect the surgical incision with the naked eye due to skin wrinkles and body hair after surgery.

Undoubtedly, MV is a significant improvement over traditional open surgery. With the help of a microscope, protection of the arteries and lymphatic vessels and ligation of all the veins can be attained. Although the operation time is prolonged, the surgical method achieves the best outcomes in terms of protecting the blood supply to the testes and reducing postoperative complications. MV also has obvious advantages over other procedures, including better prognosis and fewer complications, which have made this procedure a popular choice for doctors worldwide [18, 20, 39–48].

In recent years, with the help of microscopy, international researchers have proposed new surgical approaches based on this subinguinal approach and have also achieved good outcomes. In 2000, Cayan et al. [49] completed microscopic high inguinal varicocelectomy with the help of microscopy and concluded that high inguinal microscopic spermatic vein ligation achieves better treatment results and fewer complications than the traditional open retroperitoneal approach. In 2005, Orhan et al. [50] considered that the number of ligated veins in the high inguinal position was fewer than that in the subinguinal position; furthermore, the probability of postoperative recurrence was lower in high inguinal surgery. In 2012, Shiraishi et al. [51] presented the results of microscopic high ligation and argued that high ligation has greater advantages in terms of reduced postoperative pain and shorter operative time because there are fewer and higher venous branches. Furthermore, in 2016, Shiraishi et al. [52] compared treatment with high inguinal and subinguinal approaches, and they concluded that the treatment outcome was similar. The high inguinal approach was easier to perform, and the smaller number of veins and thicker arteries facilitated protection of the arteries and shortened the operation time. Lv et al. [21] found that the microscopic subinguinal approach had superior safety and fewer complications than the other three approaches: microscopic high inguinal, microscopic retroperitoneal and laparoscopic surgery. In 2019, Demirdöğen et al. [53] showed that the therapeutic effects and complications of varicocelectomy through the subinguinal and internal inguinal regions were similar.

Most doctors believe that the complications of the subinguinal approach are lower than those of the high inguinal approach, which has difficulty dealing with the external spermatic vein and delivery of the testis. We think that varicocelectomy with the subinguinal approach can avoid cutting muscles, tendon sheaths, and other tissues as much as possible, which will shorten the recovery time after the operation. Additionally, the external spermatic vein and the vas deferens vein can be ligated easily. Meanwhile, a subinguinal approach can be performed with easy testis delivery. Although the efficacy of this approach is controversial [54], it gives the surgeon an additional option. The incision is smaller with a lower position, which better meets the esthetic requirements of patients. Moreover, the recurrence rate and other complications after microscopic subinguinal varicocelectomy can be minimized by carefully identifying the veins under the microscope during the operation.

Surgical treatment of varicocele can alleviate symptoms in male patients with low testosterone, testicular pain, or infertility. Subinguinal surgical approach under the microscope, in accordance with previous research, has been widely promoted in China since 2010 [55], and it is favored by andrologists and patients. In the past few years, we performed microscopic subinguinal varicocelectomy and accumulated some surgical experience. Due to the increase in patients' esthetic requirements and better in-depth understanding of anatomy, we have adopted a lower position. MV for the treatment of varicocele has a similar therapeutic effect to that reported in the literature we reviewed, with a smaller incision and faster healing. There is less fat at the junction between the scrotum and lower abdominal perineum skin. Thus, the spermatic cord runs shallowly. The position of the spermatic cord can be approximated by palpation with two fingers, which is helpful for positioning the

incision during the operation. Less subcutaneous fat puts less pressure on both sides of the spermatic cord after the spermatic cord is pulled out of the body. This makes pulsation of the artery clearer and easier to identify during the operation. Additionally, less subcutaneous fat greatly reduces the probability of wound infection and fat liquefaction. An incision that is only 1–1.5 cm along the skin texture can meet the esthetic requirements of patients. Furthermore, if the surgeon wants to perform the SSI approach with testis delivery, only a slight extension of the incision along the skin line is needed. Based on our comprehensive analysis of surgical complications and therapeutic effects, we conclude that our surgical approach is both safe and effective.

And there are also some limitations in our research: pain was quantified based on the patient's subjective feelings and the use of a pain scoring questionnaire was ignored. The operation time not mentioned in the research, according to doctors' experience, it's almost similar with classical MV. And due to the fact that the impact on female pregnancy rate not only requires good sperm quality in males, but also many factors in females, we did not take pregnancy rate into account when calculating the outcome of varicocele.

5. Conclusion

We analyzed the outcomes of 772 patients who underwent microscopic SSI varicocelectomy at our hospitals. We concluded that our surgical approach achieves outcomes that are comparable to those of other MVs, with the advantages of small incisions with fewer complications. Therefore, this surgical approach can be routinely performed for MV.

Data Availability

The original data and pictures are saved by the corresponding author, which can be shared upon reasonable request.

Ethical Approval

This study was approved by the Ethics Committee of Sir Run Run Shaw Hospital, Zhejiang University School of Medicine (approval no.: 2022-0406).

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Zhuanxin Jiang, Ming Shen, and Chong Xie conceived the study. Hanchao Liu, Rui Chen, Xiaolong Wu, Mingxiao Zhang, Zhengzheng Li, Lin Hua, Junfeng Zhan, Biao Dong, Zhenqing Wang, Zhuolun Sun, Xiaotao Li, Jiaqin Liu, and Xiaodong Wang provided samples and clinical data. Chong Xie performed statistical analyses. Hanchao Liu, Rui Chen, and Xiaolong Wu wrote the manuscript. All authors contributed to the article and approved the final version of the manuscript. Hanchao Liu, Rui Chen, and Xiaolong Wu contributed equally to this work.

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