Original Article

Testicular ultrasonic microvascular density in assessing spermatogenesis and predicting successful sperm retrieval

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Background: The relationship between microcirculatory disorders and testicular spermatogenesis is an area of ongoing interest among urologists. The objective of this prospective observational study was to investigate the correlation between testicular microcirculation and spermatogenesis, as well as the predictive value of ultrasonic microvascular density (UMVD) and ultrasonographic volume estimation (UVE) in successful sperm retrieval among men with non-obstructive azoospermia (NOA).

Methods: Testicular UMVD derived from Angio PLUS™ Planwave Ultrasensitive Imaging (AP), UVE were obtained. Participants were divided into 4 groups (normozoospermia; asthenozoospermia, teratozoospermia, or asthenoteratozoospermia; oligozoospermia; NOA).

Results: The study included a total of 875 participants. No significant difference was found in UMVD-mean between different semen groups (P>0.05). A total of 108 participants with NOA underwent microdissection testicular sperm extraction (micro-TESE). Participants with successful sperm retrieval (40 cases) showed significant differences in testicular UMVD and UVE compared to those with negative retrieval (68 cases) (P<0.01). We generated receiver operating characteristic (ROC) curves for UMVD and testicular UVE to differentiate participants with successful sperm retrieval from those without. The area under the curve (AUC) was 0.760 [95% confidence interval (CI): 0.658–0.849, P<0.01] for UMVD and 0.716 (95% CI: 0.609–0.822, P<0.01) for testicular UVE, respectively. The optimal cutoff value was determined based on the maximum Youden index. When UMVD was set at 28.50/cm^2, its sensitivity and specificity were calculated as 57.5% and 85.3%, respectively. For testicular UVE, a cutoff value of 8.94 mL resulted in a sensitivity of 60.0% and specificity of 82.4%. Combining UMVD with testicular UVE improved diagnostic performance (AUC: 0.856, 95% CI: 0.772–0.929, P<0.01) with a sensitivity of 79.4% and specificity of 77.5%.

Conclusions: The present study demonstrates the utility of AP as a predictive tool for successful sperm retrieval prior to micro-TESE. Furthermore, the combination of testicular UMVD and UVE provides a highly valuable diagnostic approach for predicting micro-TESE success and can be routinely implemented before the procedure. A testicular UMVD exceeding 28.50/cm^2 and a testicular UVE larger than 8.94 mL strongly indicate favorable outcomes in terms of sperm retrieval.

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Introduction

In recent years, there has been an increasing focus on declining sperm count and human male infertility. According to the World Health Organization (WHO) statistical results, 9% of couples worldwide have problems with fertility, and male factors account for more than 50% of fertility problems (1,2). A meta-analysis has shown that sperm concentration declined by 0.93% per year and by 41.5% between 1973 and 2018 (3). Azoospermia is the most serious manifestation of male infertility and occurs in approximately 5–10% of male infertility cases, with non-obstructive azoospermia (NOA) accounting for 60% of these cases (4,5).

The testes have a rich, complex vascular system. A stable blood supply plays an extremely important role in maintaining the normal function of the testes and their internal environment (6). Testicular microcirculation disorders are not uncommon in clinical practice, most commonly in varicocele (7), but also in chronic diseases that cause systemic microcirculation disorders. The relationship between microcirculation disorders and chronic diseases has been a hot topic of ongoing research (8,9), and the relationship between microcirculation disorders and testicular spermatogenesis is an area of ongoing interest to urologists, but research into testicular microcirculation is still in an exploratory phase due to the specific anatomy of the testis and the limitations of technology. It has been reported that better-quality sperm tend to be found in areas of the testis with more abundant blood perfusion (10). Therefore, finding an effective way to monitor testicular microcirculation could be expected to help to evaluate the spermatogenic function of the testis. Several studies have searched for and located microvascular-rich areas in the testis by various means, such as color Doppler, energy Doppler, and magnetic resonance imaging (MRI) (11-13). However, these techniques can only monitor the larger blood vessels in the testis and cannot accurately show the distribution of testicular microvasculature. The literature has reported that contrast-enhanced ultrasound is capable of visualizing the microvascular distribution within the testes (14,15) and identifying the optimal perfusion area. This provides guidance for microdissection testicular sperm extraction (micro-TESE) to enhance success rates of sperm retrieval (16). However, the need for contrast media and the high cost make it difficult to routinely use for microvascular density screening.

The decisive factor in obtaining biological offspring in azoospermic patients is successful sperm retrieval. Micro-TESE is considered the most reliable method for extracting sperm from the testicles (17). However, the sperm retrieval rate (SRR) of micro-TESE in patients with NOA varies between 39.1% and 46.8% as a result of significant impairment in testicular spermatogenic function (18,19). Failed micro-TESE can have significant emotional and financial implications, which can be reduced by a preoperative assessment of the probability of success. Therefore, it is necessary to explore a non-invasive method to evaluate the relationship between testicular microcirculation and spermatogenic function and to determine whether microcirculation-related parameters can be used as predictors of successful sperm retrieval before micro-TESE.

The Angio PLUS™ Planwave Ultrasensitive Imaging (AP) technique represents a state-of-the-art approach to microvascular imaging. It utilizes 2 fundamental technologies, namely 3-dimensional wall filtering and unfocused or planar waves, which eliminate the need for focusing and enable parallel emission. As a result, it significantly enhances the image frame rate and improves the level of microvascular imaging. Consequently, it becomes effortless to capture specific phenomena caused by rapid blood flow. The AP technology maintains exceptional quality in 2-dimensional imaging, while also enhancing color sensitivity and spatial resolution significantly, and effectively eliminating noticeable motion artifacts (20,21). Moreover, AP has the capability to offer data regarding blood circulation in vessels with a diameter exceeding 50 μm. Liu *et al.* have found that AP can improve the detection rate of the typical polar vessel and internal tiny blood vessels commonly associated with parathyroid lesions (21). Wang *et al.* found that AP can display

more internal small vessels in benign and malignant breast lesions (20). Considering the advantages of AP in microvascular imaging, it is perfectly suited for evaluating the microcirculation of the testicles. The primary outcome of our study, testicular ultrasonic microvascular density (UMVD), was quantified as the number of microvessels per cm^2 obtained by AP within the designated region of interest in the testis.

Therefore, the objective of this research was to examine the correlation between testicular UMVD obtained from AP ultrasonographic volume estimation (UVE) and spermatogenic function in males with infertility, as well as to determine if UMVD could serve as a prognostic indicator for successful sperm retrieval in individuals with NOA. We present this article in accordance with the STARD reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-24-26/rc).

Methods

Participant screening and enrollment

This prospective observational study was carried out in accordance with the Declaration of Helsinki (as revised in 2013) and approved by the Ethics Committee of Shengjing Hospital of China Medical University (No. 2020PS123J). All participants provided written informed consent prior to their involvement in this study. Initially, a total of 912 consecutive individuals seeking reproductive medical services at our hospital were enrolled between December 2020 and January 2022. Rigorous inclusion and exclusion criteria were established prior to the study in order to minimize any potential bias in participant selection.

The inclusion criteria for participant selection were as follows: (I) individuals who had a scrotal ultrasound and AP examination; (II) individuals who had semen analysis conducted within 7 days before or after the ultrasound and AP examination, considering that semen examination requires semen collection after a 3–7 day abstinence period; (III) individuals with NOA underwent micro-TESE within 2 weeks following the ultrasound and AP examination according to the normal treatment process of our hospital.

The exclusion criteria were as follows: (I) ultrasound findings that might affect the measurement of testicular microcirculation, such as testicular masses, severe microlithiasis, cryptorchidism, severe hydrocele, and acute epididymitis; (II) factors that could affect ejaculation, such as a history of urethral reconstruction surgery, retrograde ejaculation, and obstructive azoospermia, resulting in inaccurate assessment of spermatogenetic status of testis; (III) testicular biopsy performed within the past 3 months; (IV) participants with NOA who did not undergo micro-TESE procedure; (V) inability to obtain satisfactory images due to various reasons.

Instruments and methods

The scrotal ultrasound and AP examinations were conducted using an ultrasound diagnostic imaging system called Aixplorer (SuperSonic Imagine, Aix en Provence, France) along with a linear transducer operating at frequencies ranging from 4 to 15 MHz. The radiologist who performed the scrotal ultrasound and AP examinations possessed over a decade of experience in this specific field.

All participants underwent a supine examination. Initially, a grayscale ultrasound was conducted on the scrotum to assess its contents and determine the position, shape, dimensions, and echogenicity of the testicles. The dimensions of the testis, including its length, width, and height, were recorded in order to determine the testicular UVE. The calculation was performed using Lambert's formula: testicular UVE (mL) is obtained by multiplying the product of length, width, and height by a factor of 0.71 (22). Left and right testicular UVEs and bilateral mean testicular UVEs were recorded as UVE-L, UVE-R, and UVE-mean.

The AP examination was conducted on a section that intersected with the centripetal arteries at a right angle. The detection area encompassed the entirety of the section. The gain setting was fine-tuned to its optimal level in order to eliminate interference. The operator avoided exerting pressure on the testis using the transducer in order to minimize the risk of vascular collapse during the AP examination. As depicted in *Figure 1*, images containing easily identifiable microvessels were archived. The archived images underwent separate evaluations by 2 proficient radiologists. The assessment of UMVD was conducted in a selected region measuring 1 cm^2 at the central part of the testis, where all visible vessels were meticulously counted. Then, 2 radiologists, who were blind with the clinical information and semen analysis results, independently conducted vessel counting within this area and documented it as UMVD-1 and UMVD-2. The average of UMVD-1 and UMVD-2 of bilateral testes were recorded as UMVD-R and UMVD-L for further statistical examination. The average value of UMVD-R and UMVD-L within each participant was recorded as UMVD-mean.

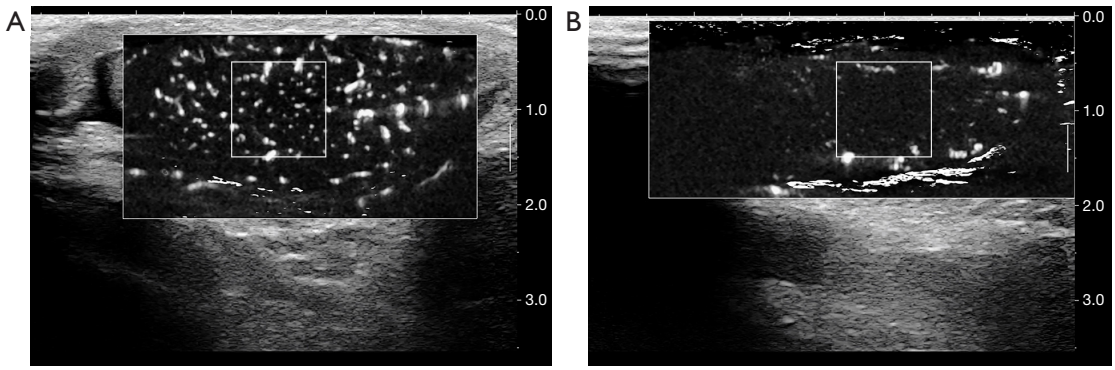

Figure 1 The testicular microcirculation imaging derived from Angio PLUS™ Planwave Ultrasensitive Imaging. (A) The maximum longitudinal section of the right testicle of a 32-year-old man with successful sperm retrieval, whose UMVD-R was 39 /cm^2, whose UVE-R was 8.1 cm^2; (B) the maximum longitudinal section of the right testicle of a 30-year-old man with negative sperm retrieval, whose UMVD-R was 7/cm^2, whose UVE-R was 3.4 cm^2. UMVD-R, ultrasonic microvascular density; UVE-R, testicular ultrasonographic volume estimation.

Semen collection and analysis

After refraining from sexual activity for a period of 3–7 days, individuals provided semen samples through self-stimulation in a designated room for semen collection. Subsequently, these samples were subjected to analysis following the protocols outlined by the World Health Organization (WHO) in 2010.

Participant grouping according to semen results

The semen analysis procedures remain consistent between the fifth and sixth editions. Consequently, participants were categorized into 4 groups based on their semen results using the 2021 WHO criteria (as outlined in the WHO Laboratory Manual for the Examination and Processing of Human Semen, 6th edition). Group I comprised individuals with normozoospermia, whereas Group II included those with asthenozoospermia, teratozoospermia, or asthenoteratozoospermia. Group III consisted of individuals with oligozoospermia, and finally, Group IV comprised individuals diagnosed with NOA.

Micro-TESE

Micro-TESE was performed by the same urologist within 2 weeks of conventional ultrasound and AP examination, and the result of the sperm retrieval was recorded.

Sample size

The sample size was determined using PASS 15.0 software (Number Cruncher Statistical Software, LLC, Kaysville, UT, USA). In a single factor analysis of variance (ANOVA) study, sample sizes of 288, 432, 144, and 144 were obtained from the 4 semen groups whose means were to be compared. The total sample of 1,008 cases achieved 99% power to detect a difference of at least 0.50 using the Tukey-Kramer (pairwise) multiple comparison test at a 0.0100 significance level. The common standard deviation within a group was assumed to be 4.00. After conducting the experiment, we discovered that there was no statistically significant difference in UMVD among the different semen groups. Then, based on our preliminary experiment, the area under the receiver operating characteristic (ROC) curves (AUCs) for UVE or UMVD and combined data in distinguishing successful from negative sperm retrieval were found to be 0.70 and 0.85, respectively. We employed tests for 2 ROC curves to estimate the required sample size. With a power of 90% and an alpha level of 5% (2-sided), the minimum sample size per group was calculated as 52.

Statistical analysis

The statistical analysis was conducted using IBM SPSS Statistics for Windows, Version 25.0 software (IBM Corp., Armonk, NY, USA). The preliminary analysis was performed to describe the age, body mass index (BMI), testicular UMVD, UVE, and semen analysis results of participants. The Kolmogorov-Smirnov normality test was utilized to evaluate the distribution's normality. Continuous variables were presented as mean ± standard deviation or median (25th–75th percentiles), whereas categorical

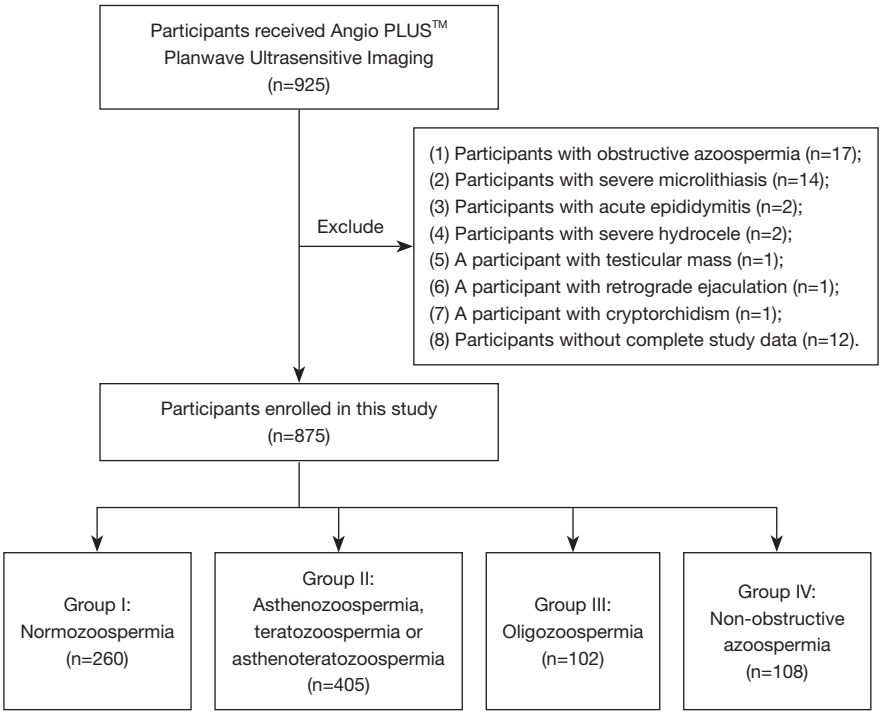

Figure 2 Participant screening and enrollment.

variables were expressed as frequencies (percentages). Group comparisons were conducted using a *t*-test, Mann-Whitney U test, or chi-square test. The interobserver agreement of the 2 radiologists was evaluated using the intraclass correlation coefficient (ICC). The ROC curves were utilized to evaluate the predictive value of testicular UMVD, testicular UVE, and their combination in distinguishing between individuals with successful and negative sperm retrieval. Sensitivities, specificities, and AUCs were computed. The cut-off values were determined based on the Youden indexes. A statistically significant difference was indicated by a P value less than 0.05.

Results

Participant screening and enrollment

The process of participant screening and enrollment is depicted in *Figure 2*. A total of 875 individuals were included in the study.

Inter-observer agreement for the 2 radiologists

There was a strong level of concordance observed between UMVD-1 and UMVD-2, with an ICC value of 0.837 [95% confidence interval (CI): 0.813–0.857, P<0.01].

Age, BMI, testicular UMVD, testicular UVE, and semen analysis results in varying semen groups

Age, BMI, UMVD-L, UMVD-R, UMVD-mean, UVE-L, UVE-R, UVE-mean, sperm concentration, total sperm number, total motility, and progressive motility in different semen groups are presented in *Table 1*. No significant differences were observed in the UMVD-L, UMVD-R, and UMVD-mean between the semen groups (P>0.05). Positively correlated with sperm concentration, the UVE-L, UVE-R, and UVE-mean exhibited a significant statistical difference among semen groups (P<0.01). A significant disparity was found in age among the semen groups (P<0.01), although there was considerable overlap between these groups.

Varicocele

As presented in Table S1, no significant differences were observed in the UMVD-L, UMVD-R, UMVD-mean, UVE-L, UVE-R, UVE-mean, sperm concentration, and total sperm number between participants with and without

Table 1 Parameters comparing participants with varying semen groups

Variables	Total (n=875)	Group I (n=260)	Group II (n=405)	Group III (n=102)	Group IV (n=108)	P value
Varicocele grade						<0.001
0	604 (69.029)	200 (76.923)	265 (65.432)	53 (51.961)	86 (79.630)	
1	151 (17.257)	36 (13.846)	73 (18.025)	32 (31.373)	10 (9.259)	
2	71 (8.114)	14 (5.385)	39 (9.630)	10 (9.804)	8 (7.407)	
3	49 (5.600)	10 (3.846)	28 (6.914)	7 (6.863)	4 (3.704)	
Age (years)	33.000 [30.000, 36.000]	32.000 [30.000, 36.000]	34.000 [31.000, 37.000]	33.000 [31.000, 37.000]	31.000 [29.000, 35.000]	<0.001
BMI (kg/m^2)	26.100 [23.400, 28.300]	26.300 [23.800, 28.400]	26.100 [23.100, 28.400]	25.700 [23.400, 27.800]	25.700 [23.200, 27.800]	0.664
UMVD-R (per cm^2)	24.000 [20.000, 29.000]	24.000 [20.000, 28.000]	24.000 [20.000, 29.000]	25.000 [19.000, 30.000]	23.000 [16.000, 30.000]	0.224
UMVD-L (per cm^2)	25.000 [20.000, 29.000]	25.000 [21.000, 29.000]	25.000 [21.000, 29.000]	25.000 [19.000, 30.000]	24.000 [18.000, 32.000]	0.51
UMVD-mean (per cm^2)	24.500 [20.500, 29.000]	24.000 [20.500, 28.000]	24.500 [21.000, 28.500]	24.500 [18.500, 29.500]	24.000 [18.000, 30.000]	0.358
Sperm concentration (10^6 per mL)	37.900 [16.860, 65.490]	61.470 [42.490, 90.730]	41.000 [27.620, 64.250]	5.790 [2.290, 9.320]	0.000 [0.000, 0.000]	<0.001
Total sperm number (10^6 per ejaculate)	126.200 [52.260, 227.360]	206.980 [140.800, 287.240]	140.800 [92.540, 240.670]	19.280 [6.870, 30.840]	0.000 [0.000, 0.000]	<0.001
Total motility (PR + NP, %)	27.880 [12.100, 41.250]	44.910 [39.620, 53.680]	24.400 [14.740, 30.700]	14.780 [6.420, 27.110]	0.000 [0.000, 0.000]	<0.001
Progressive motility (PR, %)	34.740 [15.460, 49.360]	55.770 [47.760, 65.000]	30.450 [19.760, 38.530]	19.480 [10.090, 32.050]	0.000 [0.000, 0.000]	<0.001
UVE-L (mL)	13.290 [10.980, 15.880]	14.380 [12.460, 16.980]	13.960 [11.770, 16.100]	11.660 [9.030, 14.200]	7.010 [4.650, 10.550]	<0.001
UVE-R (mL)	13.720 [11.010, 16.280]	14.770 [12.410, 17.060]	14.200 [11.960, 16.460]	11.960 [9.990, 14.650]	6.360 [4.800, 10.550]	<0.001
UVE-mean (mL)	13.545 [11.035, 15.935]	14.635 [12.480, 16.975]	14.110 [11.930, 16.190]	11.990 [9.270, 14.300]	6.635 [5.050, 10.705]	<0.001

Data are presented as median [IQR] or number (%). Group I, participants with normozoospermia; Group II, participants with asthenozoospermia, teratozoospermia, or asthenoteratozoospermia; Group III, participants with oligozoospermia; Group IV, participants with non-obstructive azoospermia. BMI, body mass index; UMVD-R, ultrasonic microvascular density of the right testis; UMVD-L, ultrasonic microvascular density of the left testis; UMVD-mean, the mean ultrasonic microvascular density of bilateral testes; PR, progressive motility; NP, non-progressive motility; UVE-R, testicular ultrasonographic volume estimation of the right testis; UVE-L, testicular ultrasonographic volume estimation of the left testis; UVE-mean, the mean testicular ultrasonographic volume estimation of bilateral testes; IQR, interquartile range.

varicocele (P>0.05). Varicocele participants were found to be significantly older than non-varicocele participants (P<0.05). Additionally, the BMI of varicocele participants was significantly lower compared to that of non-varicocele participants (P<0.01). Furthermore, the varicocele group exhibited significantly lower total sperm motility and progressive sperm motility in comparison to the non-varicocele group (P<0.01).

As presented in Table S2, there were no statistically significant differences observed in the UMVD-L, UMVD-R, UMVD-mean, UVE-L, UVE-R, UVE-mean, sperm concentration, and total sperm number among

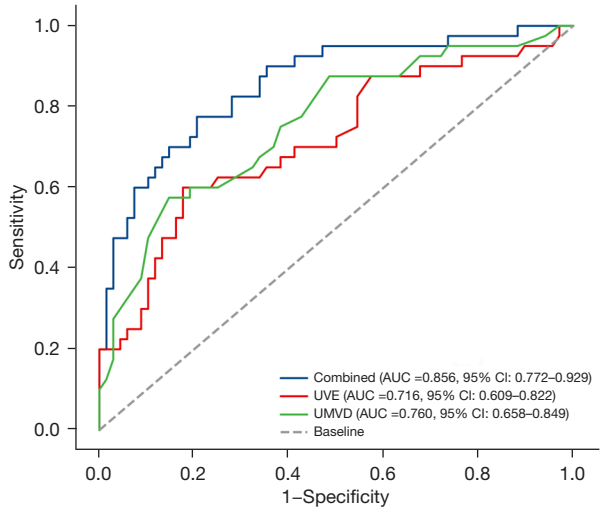

Figure 3 ROC curves of UMVD, testicular UVE and both in identifying participants with successful sperm retrieval. AUC, area under the curve; CI, confidence interval; UVE, testicular ultrasonographic volume estimation; UMVD, ultrasonic microvascular density; ROC, receiver operating characteristic.

participants with different grades of varicocele (P>0.05). However, significant differences were found in age, BMI, sperm motility, and progressive sperm motility among participants with different grades of varicocele (P<0.05).

ROC curves of testicular UMVD, UVE, and their combination in the identification of individuals with successful sperm retrieval (Figure 3)

In our study, the number of testes with successful sperm retrieval was 40 (40/108) with the median values of age, UMVD, and UVE of 31.50 (28.25, 35.00) years, 30.00 (22.25, 34.00)/cm^2, and 9.91 (5.73, 13.74) mL, respectively. The number of participants with negative sperm retrieval was 68 (68/108) with the median values of age, UMVD, and UVE of 31.00 (28.25, 35.00) years, 19.00 (13.00, 26.75)/cm^2, and 5.81 (3.97, 7.91) mL, respectively. There were significant differences in UMVD and UVE between participants with successful and negative sperm retrieval (P<0.01). We generated ROC curves for UMVD and UVE in order to differentiate between participants who had successful sperm retrieval and those who did not. The AUC was 0.760 (95% CI: 0.658–0.849, P<0.01) for UMVD and 0.716 (95% CI: 0.609–0.822, P<0.01) for UVE, respectively. The optimal cutoff value was determined based on the maximum Youden index. When the cutoff value of UMVD was set at 28.50/cm^2, its sensitivity and specificity were calculated as 57.5% and 85.3%, respectively. When the cutoff value of UVE was set at 8.94 mL, its sensitivity and specificity were calculated as 60.0% and 82.4%, respectively. Combining UMVD with UVE improved their diagnostic performance with an AUC of 0.856 (95% CI: 0.772–0.929, P<0.01); sensitivity and specificity were calculated as 79.4% and 77.5%, respectively.

Discussion

In our study, we observed that the utilization of testicular UMVD is not a viable approach for evaluating testicular spermatogenic function. However, when combined with UVE, testicular UMVD can serve as a predictive tool for assessing the success rate of micro-TESE in men with NOA.

Currently, the study of testicular microcirculation is limited due to technical constraints and ethical considerations, resulting in a lack of available literature on this subject matter. Unfortunately, despite our preliminary investigation, no noticeable differences were observed in testicular UMVD among the semen groups. This may suggest that impaired testicular microcirculation does not play a significant role in determining spermatogenic dysfunction.

Varicocele is the most common factor affecting testicular microcirculation. Varicocele has also been recognized as one of the most prevalent treatable disorders impacting semen quality. Nevertheless, it is worth noting that 75% of individuals diagnosed with varicocele exhibit fertility, and 80% possess normal semen parameters (23). In our study, we found no significant difference in testicular UMVD between participants with and without varicocele. Furthermore, there was no observed variation in testicular UMVD among patients with different severities of varicocele, indicating that testicular microcirculation disorder may not be the determining factor for testicular spermatogenic dysfunction in participants with varicocele.

Urologists are constantly exploring predictors of successful sperm retrieval in patients with NOA, to gain a comprehensive understanding of the patient's testicular status before surgery, adjust treatment plans promptly, and improve outcomes. Histopathology is the most powerful predictor of SRR in micro-TESE of NOA patients (24) and has long been used in clinical practice. However, diagnostic biopsy itself is an invasive procedure with many complications, including pain, infection, bleeding, scar tissue formation, post-operative hypogonadism, and removal of the focal spermatogenic area (25). In addition, performing a diagnostic before micro-

TESE is equivalent to performing the procedure twice, which is difficult for the patient to accept. All factors considered, there is an urgent need to discover a non-invasive diagnostic method to adapt treatment plans and avoid unnecessary surgical interventions.

The present study has suggested a potential correlation between testicular blood perfusion and focal spermatogenesis (26). Color Doppler flow imaging is the most commonly used clinical imaging method for blood flow, allowing clear visualization of the testicular artery and its branches, as well as the larger vessels within the testis. However, Schwarzer *et al.* (27) found that sperm extraction around the rete testis and great blood vessels did not improve the success rate of sperm extraction. Power Doppler ultrasound improves the ability to detect low-velocity blood flow. According to Har-Toov *et al.*'s research (12), utilizing power Doppler ultrasound guidance eliminates the requirement for numerous random biopsies and enhances the efficacy of identifying viable sperm cells within testicular tissue. Nevertheless, technical constraints result in a low diagnostic sensitivity rate of 47.3%. Previous studies have indicated a strong correlation between microvascular density and spermatogenic function in the testes (12,26). Advancements in technology have provided researchers and clinicians with the opportunity to investigate the microcirculation of testicles, enabling them to gain valuable understanding regarding its significance in predicting the success of sperm retrieval. AP is a more advanced microvascular imaging technique that maintains the workflow characteristics of color Doppler flow imaging and is easy to master. The testicular vessels that could be displayed by AP are the centripetal arteries, the centrifugal and centripetal veins, and some of the recurrent arteries (28). Technically, it is more suitable for screening testicular microcirculation status.

This study had some shortcomings. Firstly, the pathology remains the gold standard for evaluating microvascular status and spermatogenic function. However, it was deemed unethical to collect testicular tissue from participants who did not require surgery. Therefore, histopathological information from the testes was not included in our study. Furthermore, additional research with increased sample sizes is warranted due to the relatively limited number of participants diagnosed with NOA, despite the overall substantial sample size.

Conclusions

The present study demonstrates the utility of AP as a predictive tool for successful sperm retrieval prior to micro-TESE. The combination of testicular UMVD and UVE provides a highly valuable diagnostic approach for predicting micro-TESE success and can be routinely implemented before the procedure. A testicular UMVD exceeding 28.50/cm^2 and a testicular UVE larger than 8.94 mL strongly indicate favorable outcomes in terms of sperm retrieval.

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Footnote

Reporting Checklist: The authors have completed the STARD reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-24-26/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-24-26/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and was approved by the Ethics Committee of Shengjing Hospital of China Medical University (No. 2020PS123J). Written informed consent was provided by all participants.

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