

·Clinical Experience·

Relationship between testicular volume and testicular function: comparison of the Prader orchidometric and ultrasonographic measurements in patients with infertility

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Abstract

Aim: To evaluate the relationship between testicular function and testicular volume measured by using Prader orchidometry and ultrasonography (US) to determine the critical testicular volume indicating normal testicular function by each method. **Methods:** Total testicular volume (right plus left testicular volume) was measured in 794 testes in 397 men with infertility (mean age, 35.6 years) using a Prader orchidometer and also by ultrasonography. Ultrasonographic testicular volumes were calculated as length \times width \times height \times 0.71. To evaluate volume-function relationships, patients were divided into 10 groups representing 5-mL increments of total testicular volume by each method from below 10 mL to 50 mL or more. **Results:** Mean total testicular volume based on Prader orchidometry and US were 36.8 mL and 26.3 mL, respectively. Semen volume, sperm density, total sperm count, total motile sperm count, and serum FSH, LH, and testosterone all correlated significantly with total testicular volume measured by either method. Mean sperm density was in the oligozoospermic range in patients with total testicular volume below 35 mL by orchidometry or below 20 mL by ultrasonography. Mean total sperm count was subnormal in patients with total testicular volume below 30 mL by orchidometry or under 20 mL by ultrasonography. **Conclusion:** Testicular volume measured by either ultrasonography or Prader orchidometry correlated significantly with testicular function. However, critical total testicular volume indicating normal or nearly normal testicular function was 30 mL to 35 mL using Prader orchidometer and 20 mL using ultrasonography. Prader orchidometry morphometrically and functionally overestimated the testicular volume in comparison to US. (*Asian J Androl* 2008 Mar; 10: 319–324)

Keywords: orchidometer; ultrasonography; testicular volume; testicular function

1 Introduction

Since the seminiferous tubules comprise 70%–80%

of the testicular mass, testicular volume reflects spermatogenesis [1]. Testicular volume is related to semen profiles in infertile men, and it has been useful in estimating spermatogenesis [2–9]. Current testicular volume measurement methods involve the use of calipers, an orchidometer or ultrasonography (US) [2–9]. Although orchidometry is a conventional method that has been used for about 40 years [10, 11], US is generally recognized as the most accurate based upon comparison with actual

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testicular volume [9, 12–15]. Testicular volumes calculated using the ultrasonographic formula, length (L) × width (W) × height (H) × 0.71, provide the closest estimate of actual volume [12, 13]. However, the cut-off testicular volume that indicates normal testicular function is not established, although a few studies using punched-out orchidometers have sought to determine the critical testicular volume consistent with normal testicular function [2, 3]. There is a lack of sufficient evidence to support the relationships between testicular volume and testicular function [2–9].

In the present study, the relationships between testicular function and testicular volumes obtained using Prader orchidometry and US using the formula $L \times W \times H \times 0.71$ were evaluated. In addition, using each method, critical testicular volume indicating normal testicular function was determined.

2 Materials and methods

Among 488 infertile men (mean age ± SD, 35.8 ± 5.5 years) with testicular volume measurements obtained using US and Prader orchidometry at our male infertility clinic, 91 with any pathology influencing testicular volume or semen profiles except for a varicocele were excluded [16, 17]. Of those 91 patients, 42 had a history of genitourinary infection, 15 had a ductal obstruction, 12 had ejaculatory dysfunction, nine had a history of cryptorchidism, five had a chromosomal abnormality, three had a hydrocele, three had a history of chemotherapy for a malignant tumor, one had chronic renal failure, and one had a history of an orchiectomy for unilateral testicular tumor. Accordingly, the present study included 397 infertile men (794 testes; mean age ± SD, 35.6 ± 5.3 years). The scrotal contents were examined by palpation to assess the location, size and consistency of the testis and epididymis. Of these 397 patients, 123 had a left clinical varicocele and 10 had right and left clinical varicoceles. Orchidometric testicular volumes were obtained by two experienced urologists with similar expertise in measurement after stretching the scrotal skin over the testis in a warm room. Comparisons were made with 12 solid ellipsoid models constituting the Prader orchidometer, ranging in volume from 1 mL to 25 mL (1 to 6, 8, 10, 12, 15, 20 and 25 mL) [10].

High-frequency US was performed by an experienced examiner using 5 and 7.5 MHz transducers (ALOKA

SSD2000, Tokyo, Japan) with subjects in a supine position. Using light pressure to avoid distortion of testicular shape, gray-scale images of the testes were obtained in transverse and longitudinal planes. At least three separate transverse and longitudinal images of each testis were obtained. Testicular length, width and height were measured using electronic calipers, excluding the epididymis. The largest measurement obtained for each testicular dimension was used for volume calculation and statistical analysis. US testicular volumes were calculated using the formula $L \times W \times H \times 0.71$ based on a previous study [13].

Semen analysis was performed according to World Health Organization criteria [18]. The semen sample was collected by masturbation after 2–7 days of sexual abstinence, and delivered to the laboratory and analyzed within 1 h after ejaculation. Semen volume, sperm density, total sperm count, motility percentage and total motile sperm count were determined. Using blood samples obtained during the morning, serum follicle-stimulating hormone (FSH) and luteinizing hormone (LH) were measured using chemiluminescent immunoassays. Serum testosterone concentration was measured by radioimmunoassay. Mean intra-assay and inter-assay coefficients of variation were below 5.0% for LH, FSH and testosterone.

For an evaluation of the relationship between testicular volume and testicular function, patients were divided into 10 groups defined by total testicular volume (TTV) (a sum of the right and left testicular volumes) using Prader orchidometry and US: group A (under 10 mL), group B (10–15 mL), group C (15–20 mL), group D (20–25 mL), group E (25–30 mL), group F (30–35 mL), group G (35–40 mL), group H (40–45 mL), group I (45 to 50 mL) and group J (50 mL or more).

Simple linear regression, paired *t*-test, and the Kruskal-Wallis test were used for statistical analysis. The results are reported as the mean ± SD. A statistically significant difference was defined as $P < 0.05$.

3 Results

The mean TTV using Prader orchidometry and US were 36.8 ± 9.7 mL (range, 5.5–60) and 26.3 ± 9.5 mL (range, 3.0–71.9), respectively. The mean orchidometric TTV was larger than ultrasonographic TTV ($P < 0.001$); the orchidometer overestimated the ultrasonographic TTV by 10.5 ± 6.8 mL (range, –16.1 to 30.3). The differences

between the TTV using the two methods decreased with increasing ultrasonographic TTV (Figure 1). However, orchidometric TTV measurements correlated strongly with ultrasonographic TTV (Figure 1).

The motility percentage and total motility sperm count were not studied in azoospermic patients in any group (Tables 1 and 2). Semen volume, sperm density, total sperm count and total motile sperm count correlated with the TTV using orchidometry and US, but these parameters correlated more strongly with ultrasonographic TTV than with orchidometric TTV (Tables 1 and 2). Mean sperm density, total sperm count and total motile

sperm count increased with increasing TTV using both methods, but more clearly with the TTV obtained using US (Tables 1 and 2). Oligozoospermic mean sperm densities (below $20 \times 10^6/\text{mL}$) were seen in patients with TTV below 35 mL using orchidometry (Groups A to F) and below 20 mL using US (Groups A to C). Subnormal mean total sperm counts (below $40 \times 10^6/\text{ejaculate}$) were seen in patients with TTV below 30 mL using orchidometry (Groups A to E) and below 20 mL using US (Groups A to C). The motility percentage did not correlate with TTV using either method, and the mean motility values were below 50% in all groups.

Serum FSH and LH correlated negatively, and testosterone positively with TTV measured using either method (Tables 1 and 2). The mean FSH concentration exceeded the normal range in patients with TTV below 45 mL using orchidometry (Groups A to H) and with TTV below 30 mL using US (Groups A to E) (Tables 1 and 2). The mean LH concentration exceeded the normal range in patients with TTV below 20 mL using orchidometry (Groups A to C) and with TTV below 15 mL using US (Groups A to B). The correlation of serum testosterone concentration with TTV using either method was weak, and the mean concentrations were normal in all groups.

4 Discussion

Adequate spermatogenesis is presumed to be possible only in a testis of normal or nearly normal volume [10]. Testicular volume measured using any of Prader orchidometry, punched-out orchidometry or US significantly correlated with the parameters of testicular function, including sperm density, total sperm count, serum FSH and LH [2, 3, 6, 7, 9]. Although testicular volume measurements are considered important for assessing spermatogenesis, a cut-off value for the testicular volume that ordinarily would ensure normal testicular function has not been established. Using an orchidometer with punched-out outlines, Takihara *et al.* [3] showed that the critical mean of right and left testicular volumes (MTV) for normal or nearly normal sperm quality and quantity is 14 mL. Arai *et al.* [2] showed, using a punched-out orchidometer, that the critical TTV for normal testicular function is approximately 30 mL; and that TTV below 20 mL is associated with severe oligozoospermia (below $10 \times 10^6/\text{mL}$). However, orchidometry might overestimate the US volume, although orchidometric volumes have been shown to closely correlate with ultra-

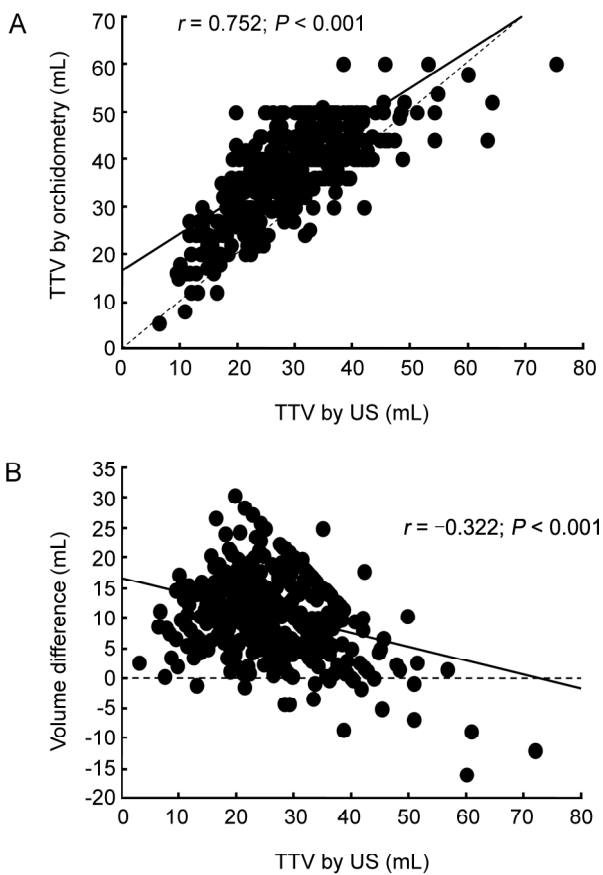


Figure 1. Correlations (solid straight lines) between total testicular volume (TTV) measurements using ultrasonography (US) and using Prader orchidometry (A), and correlations between the TTV measured using US and volume differences between Prader orchidometric and US measurements (B). (A): Correlation coefficient (r) = 0.752, $P < 0.001$. The dashed lines indicate identity (slope = 1). (B): $r = -0.322$, $P < 0.001$. The horizontal dashed lines indicate identity (slope = 0). Formula used: differences = Prader – US.

Table 1. Relationship between the total testicular volume measured by Prader orchidometry and testicular function. †: Numbers of patients without azoospermia for motility and TMSC are given in parentheses. *: Kruskal-Wallis test was used between 10 testicular volume groups. #: Simple linear regression was used to evaluate relationship between total testicular volume and each of parameters of testicular function. FSH, follicle-stimulating hormone (normal range, 2.9 to 8.2 mIU/mL). LH, luteinizing hormone (normal range, 1.8 to 5.2 mIU/mL). T, testosterone (normal range, 2.7 to 10.7 ng/mL). SV, semen volume. SD, sperm density. TSC, total sperm count. TMSC, total motile sperm count. TTV, total testicular volume. /: not analyzed because all patients were azoospermic.

Group	Testicular volume (mL)	Number of patients/	Abstinence period (days)	FSH (mIU/mL)	LH (mIU/mL)	T (ng/mL)	SV (mL)	SD ($\times 10^6$ /mL)	TSC ($\times 10^6$ /ejaculate)	Motility (%)	TMSC ($\times 10^6$ /ejaculate)
A	<10	2 (0)	5.0 \pm 0.0	64.9 \pm 8.1	16.2 \pm 9.3	3.5 \pm 2.4	1.5 \pm 0.7	0.0 \pm 0.0	0.0 \pm 0.0	/	/
B	10-15	3 (2)	5.0 \pm 0.0	37.8 \pm 10.6	9.2 \pm 3.4	3.4 \pm 1.9	2.6 \pm 1.6	0.3 \pm 0.5	0.4 \pm 0.5	5.6 \pm 7.8	0.1 \pm 0.1
C	15-20	11 (5)	5.0 \pm 1.8	31.7 \pm 14.2	7.7 \pm 4.4	3.2 \pm 0.9	3.2 \pm 1.5	1.7 \pm 3.3	6.2 \pm 16.7	34.1 \pm 27.3	8.9 \pm 17.7
D	20-25	36 (27)	4.0 \pm 1.8	21.5 \pm 12.7	5.1 \pm 2.5	4.4 \pm 1.4	2.8 \pm 1.3	15.4 \pm 34.5	37.2 \pm 64.2	31.0 \pm 26.6	20.4 \pm 32.1
E	25-30	30 (23)	5.1 \pm 1.5	15.6 \pm 7.6	4.6 \pm 1.8	4.6 \pm 1.8	2.6 \pm 1.1	12.8 \pm 24.0	24.6 \pm 30.9	27.6 \pm 20.5	9.6 \pm 11.3
F	30-35	60 (52)	4.7 \pm 1.7	11.5 \pm 7.3	3.1 \pm 1.5	4.3 \pm 1.7	3.0 \pm 1.4	16.0 \pm 15.8	51.3 \pm 63.9	24.6 \pm 15.8	15.3 \pm 29.4
G	35-40	65 (61)	4.8 \pm 1.9	9.6 \pm 4.9	3.3 \pm 1.6	4.5 \pm 2.9	2.9 \pm 1.4	31.7 \pm 37.1	85.9 \pm 90.4	31.0 \pm 18.2	27.8 \pm 32.8
H	40-45	98 (92)	5.3 \pm 1.6	8.3 \pm 5.5	2.9 \pm 1.4	4.3 \pm 1.5	3.1 \pm 1.7	45.7 \pm 48.5	145.7 \pm 203.7	32.3 \pm 19.5	51.4 \pm 66.4
I	45-50	35 (33)	5.6 \pm 1.7	7.3 \pm 3.2	3.4 \pm 1.8	3.9 \pm 1.4	2.8 \pm 1.7	49.2 \pm 65.0	107.3 \pm 129.0	33.0 \pm 17.3	38.1 \pm 50.6
J	≥ 50	57 (52)	4.4 \pm 2.1	6.5 \pm 4.1	2.6 \pm 1.0	5.2 \pm 3.0	3.4 \pm 1.6	48.5 \pm 48.1	177.9 \pm 195.0	29.7 \pm 17.5	61.1 \pm 68.4
P value*			0.602	<0.001	<0.001	0.012	0.362	<0.001	<0.001	0.155	<0.001
Correlation coefficient for TTV				-0.608	-0.457	0.108	0.115	0.342	0.35	0.075	0.306
P value#				<0.001	<0.001	0.033	0.022	<0.001	<0.001	0.164	<0.001

Table 2. Relationship between the total testicular volume measured by ultrasonography and testicular function. †: Numbers of patients without azoospermia for motility and TMSC are given in parentheses. *: Kruskal-Wallis test was used between 10 testicular volume groups. #: Simple linear regression was used to evaluate relationship between total testicular volume and each of parameters of testicular function. FSH, follicle-stimulating hormone (normal range, 2.9 to 8.2 mIU/mL). LH, luteinizing hormone (normal range, 1.8 to 5.2 mIU/mL). T, testosterone (normal range, 2.7 to 10.7 ng/mL). SV, semen volume. SD, sperm density. TSC, total sperm count. TMSC, total motile sperm count. TTV, total testicular volume.

Group	Testicular volume (mL)	Number of patients/	Abstinence period (days)	FSH (mIU/mL)	LH (mIU/mL)	T (ng/mL)	SV (mL)	SD ($\times 10^6$ /mL)	TSC ($\times 10^6$ /ejaculate)	Motility (%)	TMSC ($\times 10^6$ /ejaculate)
A	<10	12 (4)	4.5 \pm 1.6	40.0 \pm 17.9	9.2 \pm 5.2	3.6 \pm 1.3	2.8 \pm 1.5	1.7 \pm 5.7	3.8 \pm 12.5	12.8 \pm 18.9	4.4 \pm 8.7
B	10-15	27 (18)	4.0 \pm 1.8	25.2 \pm 12.4	5.7 \pm 3.5	3.8 \pm 1.2	2.5 \pm 1.1	3.9 \pm 6.3	12.0 \pm 21.2	28.4 \pm 22.9	9.0 \pm 13.8
C	15-20	69 (58)	4.7 \pm 1.8	16.2 \pm 8.9	3.9 \pm 2.0	4.3 \pm 1.5	3.0 \pm 1.5	11.1 \pm 15.5	31.9 \pm 44.6	30.2 \pm 23.0	12.3 \pm 20.4
D	20-25	78 (71)	5.1 \pm 1.8	10.7 \pm 4.9	3.6 \pm 1.6	4.7 \pm 1.6	2.9 \pm 1.4	23.6 \pm 30.6	66.3 \pm 82.0	28.6 \pm 16.6	23.2 \pm 30.4
E	25-30	88 (80)	5.3 \pm 1.7	8.4 \pm 4.0	3.0 \pm 1.5	4.4 \pm 1.7	2.9 \pm 1.2	35.8 \pm 41.0	91.9 \pm 100.8	29.2 \pm 18.4	29.8 \pm 38.8
F	30-35	58 (54)	4.8 \pm 1.6	5.8 \pm 2.7	2.9 \pm 1.4	4.6 \pm 3.2	3.2 \pm 1.7	48.8 \pm 53.3	142.8 \pm 156.7	30.7 \pm 19.3	45.5 \pm 54.0
G	35-40	38 (36)	5.0 \pm 1.8	5.8 \pm 2.7	2.6 \pm 1.2	4.2 \pm 1.4	3.4 \pm 2.1	58.5 \pm 49.0	178.9 \pm 161.6	35.4 \pm 17.5	74.5 \pm 80.7
H	40-45	13 (13)	5.0 \pm 1.6	6.2 \pm 2.4	2.7 \pm 1.1	4.5 \pm 1.1	3.0 \pm 1.1	87.0 \pm 68.7	299.7 \pm 307.5	28.3 \pm 20.2	79.8 \pm 91.9
I	45-50	7 (6)	5.2 \pm 1.8	5.1 \pm 2.2	3.4 \pm 2.1	5.0 \pm 0.9	5.1 \pm 1.5	58.4 \pm 41.8	303.9 \pm 211.8	30.7 \pm 7.9	102.1 \pm 75.5
J	≥ 50	7 (7)	4.0 \pm 2.2	3.2 \pm 1.2	2.5 \pm 0.9	6.6 \pm 7.7	3.4 \pm 1.7	84.0 \pm 73.5	352.9 \pm 455.9	36.1 \pm 19.7	99.1 \pm 83.8
P value*			0.542	<0.001	<0.001	0.278	0.061	<0.001	<0.001	0.487	<0.001
Correlation coefficient for TTV				-0.619	-0.405	0.142	0.144	0.466	0.491	0.096	0.422
P value#				<0.001	<0.001	0.005	0.004	<0.001	<0.001	0.075	<0.001

sonographic measurements, as in the present study [9, 12–15, 19, 20]. US is generally recognized as the most accurate volume measurement method, but previous US studies have varied considerably regarding the formulas used to calculate testicular volume [9, 12–15, 19, 20]. Two recent studies show testicular volume calculated using the ultrasonographic formula $L \times W \times H \times 0.71$ to be closest to the actual testicular volumes [12, 13]. The present study, using the US formula $L \times W \times H \times 0.71$, found normal sperm density in patients with a TTV over 20 mL using US, and over 35 mL using Prader orchidometry. A normal total sperm count was observed in patients with TTV over 20 mL using US and 30 mL using Prader orchidometry. In contrast, TTV below 15 mL using US and 20 mL using orchidometry was associated with severe oligozoospermia (below $5 \times 10^6/\text{mL}$).

Previous studies have shown testicular volume to correlate strongly and negatively with serum FSH and LH concentrations, respectively, which is consistent with the current data [2–4, 6, 8]. Two previous studies, using a punched-out orchidometer, showed abnormally high mean FSH and LH concentrations in patients with TTV below 30 mL and 20 mL respectively [2], or with MTV below 16 mL and 10 mL respectively [3]. In the current study, the mean FSH and LH concentrations in excess of normal were observed in patients with TTV below 45 mL and 20 mL, respectively, using orchidometry and 30 mL and 15 mL, respectively, using US. The relationship between the serum testosterone concentration and the testicular volume differs somewhat between the present and prior studies [2, 3]. A previous report stated that serum testosterone concentration correlated weakly with testicular volume, while serum testosterone was below normal in patients with MTV below 12 mL [3]. The present study also revealed a weak correlation between TTV measured using either method and serum testosterone, but the mean testosterone concentrations remained normal for all testicular sizes. These findings indicate that in small testes the Leydig cell function might be better preserved than the seminiferous tubule function, as concluded in previous reports [2, 3].

The reference value of serum FSH and LH in the present study differed from previous reports [2, 3] and, therefore, comparison of the results with those of previous reports considering serum FSH and LH might be difficult. However, for normal sperm density and total

sperm count, the critical TTV value of 30–35 mL determined with the Prader orchidometer might be higher than that of 25–30 mL with that determined with a punched-out orchidometer in a previous report, although the present study did not directly compare punched-out orchidometer with Prader orchidometer [2]. Finally, Prader orchidometry overestimated the critical testicular volumes, indicating normal sperm density and total sperm count in comparison to US. However, the present study has some limitations. First, the evaluations used no normal fertile men as controls. Therefore, critical testicular volume indicating nearly normal testicular function in this study might not be identical for fertile men. Second, 1/3 of the 397 infertile men in the present study had a clinical varicocele, which can influence testicular volume and function [16, 17]. Therefore, the distribution of patients with clinical varicocele might have influenced the results, but its prevalence in the present study is compatible to that in infertile populations [16, 17]. Third, the present study includes only Japanese infertile men. The critical testicular volume indicating nearly normal testicular function might differ in different ethnic groups [11]. However, the critical testicular volume indicating nearly normal testicular function in two previous studies using punched-out orchidometer did not substantially differ between infertile men in different ethnic groups [2, 3]. Moreover, few studies evaluate critical testicular volume indicating nearly normal testicular function using Prader orchidometry and US, although some studies show variability in testicular volume measurements depending on the methods used [9, 12–15, 19, 20]. Therefore, the present study is important for considering testicular volume measurements using ultrasonographic formula $L \times W \times H \times 0.71$, which is reported as the most accurate method, in male infertility practice [12, 13]. Finally, the critical testicular volume indicating near normal testicular function obtained statistically in the present study does not demonstrate a cut-off testicular volume ensuring a normal testicular function.

In the present study, testicular volume using either US or Prader orchidometry correlated significantly with testicular function. However, the critical total testicular volume indicating normal or nearly normal testicular function was 30–35 mL with the Prader orchidometer and 20 mL with US. Prader orchidometry morphometrically and functionally overestimated the testicular volume in comparison to US.

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