

A Testicular Tubule Evaluation Method by Ultrasonic Array Probe

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Abstract— This paper describes a testicular tubules evaluation using 1.0MHz ultrasonic array probe. In this system, we evaluate a diameter of testicular tubules. We employ an ultrasonic array probe with the center frequency of 1.0MHz. We employ evaluation index that cumulative relative frequency of amplitude values. In the experiment, we employ 24 nylon lines as the testicular tubules. Amplitude of large nylon line echo is larger than that of small nylon echo. For the evaluation, we calculate cumulative relative frequency amplitude of acquisition data. Fuzzy if-then rules are made by the cumulative relative frequency of large and small lines. We evaluate a rate of large lines among all lines by using the fuzzy MIN-MAX center-of-gravity method. In this experiment, the proposed method successfully evaluated the rate of the large lines. We changed the rate of large lines in 24 nylon lines, and tested our method 20 times for each rate. We evaluated the rate with 5.77 % in mean absolute error.

Keywords—medical system; ultrasonic; cumulative relative frequency; azoospermia; testicular tubule.

I. INTRODUCTION

Azoospermia is the term used when there is a complete absence of sperm in the ejaculate. Fifteen-20% of infertile men turn out to be azoospermia. Azoospermia is caused by two problems; a production problem which is called non-obstructive azoospermia (NOA) and a deliver problem which is called obstructive azoospermia (OA). The development of intracytoplasmic sperm injection (ICSI) opened a new era in the field of assisted reproduction and revolutionized the assisted reproductive technique protocols of couples with male factor infertility [1]. Fertilization and pregnancies can be obtained with spermatozoa recovered not only from the ejaculate, but seminiferous tubules.

The ideal technique of sperm extraction from testicle for NOA would be minimally invasive and avoid destruction of testicular function without compromising the chance of retrieval adequate numbers of spermatozoa to perform ICSI. Schlegel et al. have successfully developed the techniques with the assistance of an operating microscope as Micro-TESE [2]. The testicle can be inspected for the presence of a spermatogenically active region of normal seminiferous tubules (Diameter: 0.250mm~0.300mm), which containing many

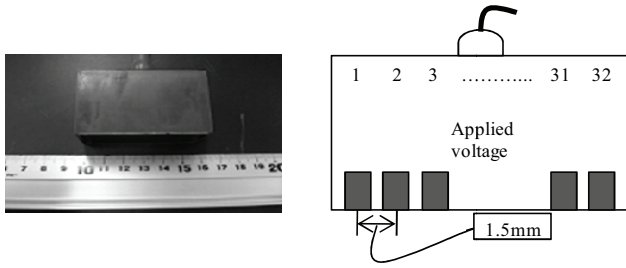
developing germ cells. Those tubules are usually larger and more opaque than tubules without sperm production, and therefore easily distinguishable from sclerotic tubules that are much smaller in diameter (Diameter: <0.150mm). In almost all patients in whom micro-TESE was successful we could identify focal spermatogenesis in dilated and opaque seminiferous tubules surrounded by shrunken tubules or fibrous tissue [3], [4].

The determination of factors that can predict successful sperm retrieval (SR) procedure can offer realistic expectations for both the couple and the physician because SR rate is at most 50% even after the introduction of micro-TESE. Additionally, the operation is high cost and physically large burden for patients. Retrospectively, we examined the differences between SR success and failure group in FSH, LH, testosterone, testicular volume and age. So far, no one could foretell about the presence of a spermatogenic focus inside an NOA testis. Therefore, we request the system that noninvasive measures the tubules heterogeneity in the testicle before micro-TESE procedure [5], [6].

In our study, we propose a testicular tubule evaluation system with a 1.0MHz ultrasonic array probe. We can noninvasively evaluate it by the ultrasonic array probe. We employ two different diameter nylon fishing lines as a small tubule and large tubule. We calculate the cumulative relative frequency of amplitude values. From the difference of the frequency of amplitude values, we derive fuzzy IF-THEN rules and make a fuzzy MIN-MAX center-of-gravity method. We then evaluate the rate of large line among all lines by the method. In our experimental results, mean absolute error was 5.77 %.

II. PRELIMINARIES

In this section, we describe the ultrasonic array probe and the experimental system used here. Fig. 1 shows the system of our ultrasonic array probe (ISL Inc., ISL1938). It consists of 32 elements in line. Center frequency of the array probe is 1.0 MHz, and each element interval is 1.5 mm. As shown in Fig. 1, a combination ultrasonic is generated by applying a voltage to several elements. The applied voltage shifts for 1 element distance [7].



(a) Ultrasonic array probe (b) The structure
Figure 1. The system of 1.0MHz ultrasonic array probe.

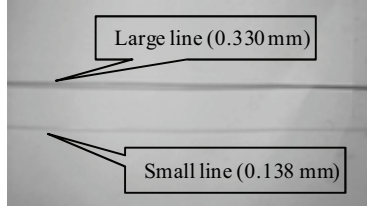


Figure 2. Large fishing line and small fishing line.

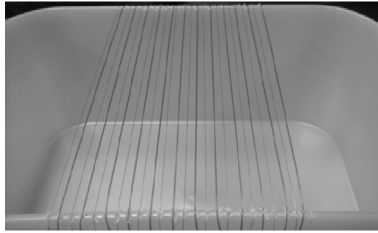


Figure 3. Object that line up 24 fishing line.

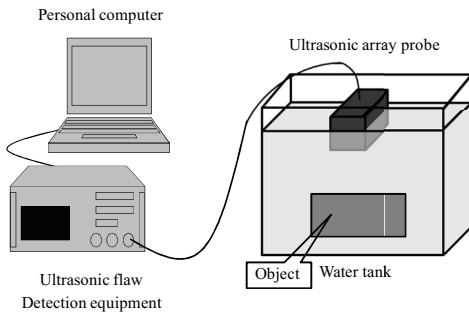


Figure 4. Ultrasonic data acquisition system.

In our experiment, we employ two different diameter nylon fishing lines as shown in Fig. 2, we employ these lines as the object. The diameter of small line is 0.138 mm and that of large line is 0.330 mm. Here, it is noted that testicular larger diameter ranged from 0.25 to 0.30 mm and smaller one is 0.15 mm. Fig. 3 shows the phantom of it. It line up 24 fishing lines in parallelism. The ultrasonic data acquisition system is shown in Fig. 4. Fig. 5 shows the data acquisition method. The sampling interval is 500 ms. The ultrasonic data are provided to a personal computer through the ultrasonic array probe.

III. LARGE LINE EVALUATION

A. Outline of the procedure

Our method consists of five steps. Firstly, we acquire the waveforms from the probes, and extract the data in the nylon lines. Secondly, we calculate the amplitude values. Thirdly, we calculate cumulative relative frequency of amplitude values. Fourthly, we apply the fuzzy-if then rules from cumulative

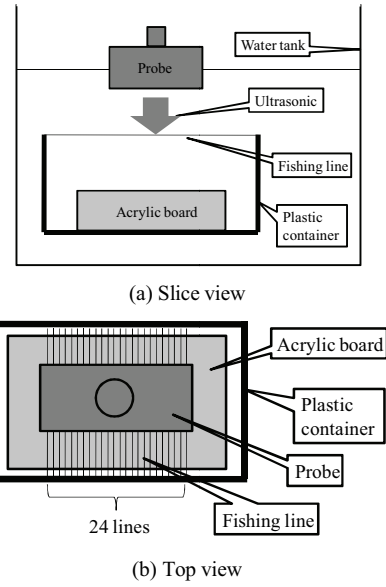
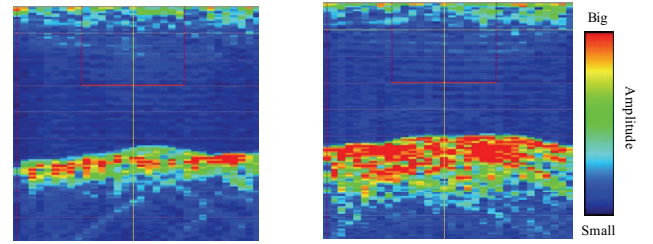


Figure 5. Ultrasonic data acquisition method.



(a) 24 small lines (b) 24 large lines
Figure 6. Examples of ultrasonic data (B-mode).

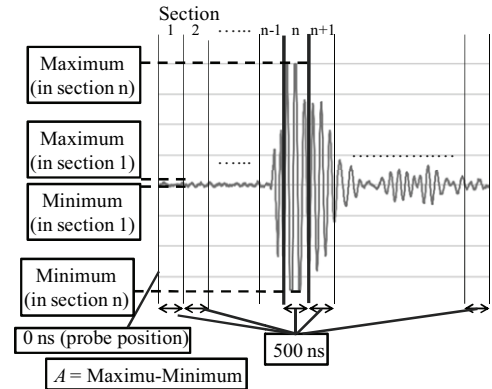


Figure 7. Calculation Amplitude

relative frequency of particular amplitude. Finally, we calculate the rate of large line among all lines by the fuzzy MIN-MAX center-of-gravity method.

B. Calculation of cumulative relative frequency of amplitude

Fig. 6 shows an example of ultrasonic data. As shown in Fig. 6, the rate of big amplitudes in the large lines is larger than that of the small lines. We use the difference of the distribution of the amplitude values for evaluating the rate of large line.

We employ the cumulative relative frequency of amplitude to compare the rate of the big amplitudes. We extract the waves of the interval 500 ns as shown in Fig. 7. We then calculate

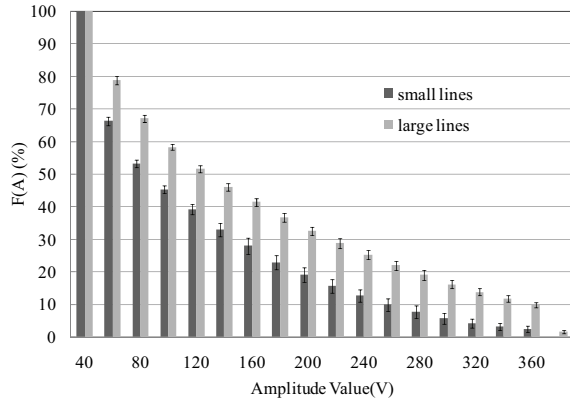
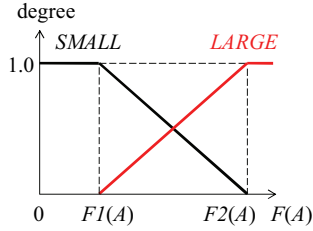
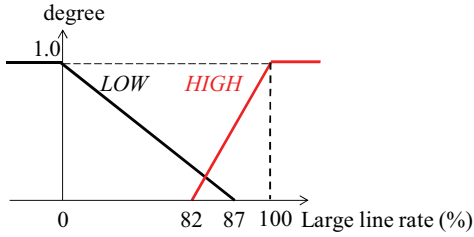


Figure 8. Average of cumulative relative frequency



(a) Input membership functions.



(b) Output membership functions.
Figure 9. Fuzzy membership functions.

peak to peak value in amplitude in every interval. In Fig. 7, the notation A denotes peak to peak value. We calculate cumulative relative frequency from relative frequency from 40 V to 400 V at the interval of 20 V. The cumulative relative frequency is calculated by (1).

$$F(A) = \sum_{X=A}^{400} f(X) \quad (1)$$

Here, the notation $F(A)$ denotes cumulative relative frequency of amplitude of A , and $f(A)$ denotes relative frequency. We show the average of $F(A)$ of 20 times of 24 small and 24 large lines in Fig. 8. As shown in Fig. 8, cumulative relative frequency of large lines is larger than that of small lines.

C. Evaluation of rate of large line

We evaluate a rate of large line in mixed lines using fuzzy inference. From Fig. 8, we obtain knowledge of the cumulative relative frequency of amplitude as follows.

Knowledge 1: The cumulative relative frequency of large line is larger than that of small lines at same amplitude value.

TABLE I. Fuzzy IF-THEN Rules

Input			Output
$F(80)$	$F(180)$	$F(200)$	Large line rate
<i>SMALL</i>	<i>SMALL</i>	<i>SMALL</i>	<i>LOW</i>
<i>SMALL</i>	<i>SMALL</i>	<i>LARGE</i>	<i>LOW</i>
<i>SMALL</i>	<i>LARGE</i>	<i>SMALL</i>	<i>LOW</i>
<i>SMALL</i>	<i>LARGE</i>	<i>LARGE</i>	<i>HIGH</i>
<i>LARGE</i>	<i>SMALL</i>	<i>SMALL</i>	<i>LOW</i>
<i>LARGE</i>	<i>SMALL</i>	<i>LARGE</i>	<i>HIGH</i>
<i>LARGE</i>	<i>LARGE</i>	<i>SMALL</i>	<i>HIGH</i>
<i>LARGE</i>	<i>LARGE</i>	<i>LARGE</i>	<i>HIGH</i>

TABLE II. Values of $F1(A)$ and $F2(A)$.

$A(V)$	$F1(A)$	$F2(A)$
80	53.22	66.98
180	22.85	36.75
200	19.02	32.51

- Knowledge 2: When amplitude value is 180, the cumulative relative frequency has the largest difference between small lines and large lines.
- Knowledge 3: When amplitude value is 80, the cumulative relative frequency has the 2nd largest difference between small lines and large lines.
- Knowledge 4: When amplitude value is 200, the cumulative relative frequency has the 3rd largest difference between small lines and large lines.

These knowledge are converted into eight fuzzy IF-THEN rules. The fuzzy IF-THEN rules are derived as shown in Table I. “LOW”, “HIGH”, “SMALL” and “LARGE” are fuzzy linguistic values, and these values are defined by fuzzy membership functions as shown in Fig. 9. The notations $F1(A)$ and $F2(A)$ denote $F(A)$ of 24 large lines and $F(A)$ of 24 small lines, respectively. To determine these values, we acquire ultrasonic data 20 times for each line set, and we calculate the average values. We show the values of $F1(A)$ and $F2(A)$ in Table II. The fuzzy IF-THEN rules are expressed by fuzzy MIN-MAX center-of-gravity method [8]. We determine a value of center of gravity as the rate of large line among all lines.

IV. EXPERIMENTAL RESULTS

We acquired ultrasonic waves by 32 elements of the ultrasonic array probe. We used eight kinds of phantoms. These are lined up from large and small lines in total 24. We acquired 20 times ultrasonic waveforms for each object. Table III shows average of the calculated large line rate and truth large line rate

TABLE III. Object and evaluation result

Object		Large line rate(%)	
N_s	N_L	evaluation result	truth
24	0	2.84	0.00
23	1	14.33	4.17
20	4	19.55	16.67
16	8	27.99	33.33
12	12	49.33	50.00
8	16	66.94	66.67
4	20	93.60	83.33
0	24	86.25	100.00

($truth = N_L / (N_s + N_L) \times 100 \%$). The notation N_s denotes number of small lines, and N_L denotes number of large lines.

Fig. 10 shows the result. The continuous line shows our evaluation result, and the dotted line shows the true value. As shown in this figure, the rate of large line is increased by the increment of the number of large line and our result accords with the truth value. The mean absolute error was then 5.77 %. The correlation coefficient the obtained was 0.98.

V. CONCLUSION

In our study, we proposed a testicular tubules evaluation system with a 1.0MHz ultrasonic array probe. We employed two different diameter nylon fishing lines as a small tubule and large tubule. In the preliminary experiment, we analyzed the difference of cumulative relative frequency of amplitude from the obtained ultrasonic data, and we found the difference of the distribution of the amplitude values. From these results, eight fuzzy IF-THEN rules were derived. The rate of large line was evaluated by fuzzy MIN-MAX center of gravity method. As the result, the evaluated rate of large line increases according to the increment of the number of large line. Then the correlation coefficient was 0.98. The experiments were done with 1.0 MHz ultrasonic waves. This experimental results suggested the high possibility to determine the larger diameter testicular tubule under the assumption that the characteristics of human testicular tubule is similar to that of the fishing line.

In the future, we will add the other indexes for optimize the fuzzy membership functions. Additionally we do experiment

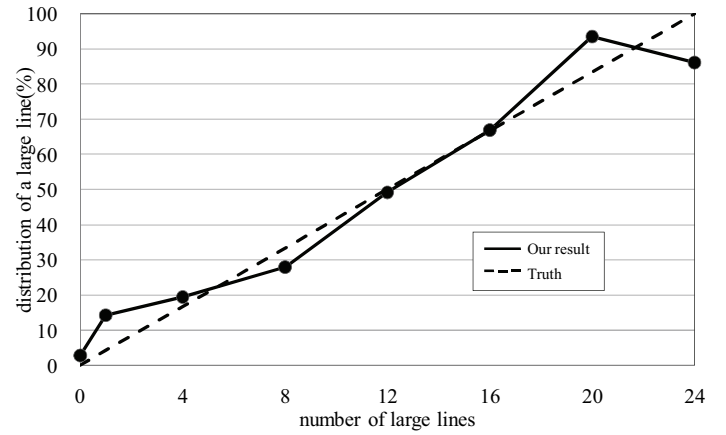


Figure 10. Result of large line rate.

with the model being nearer to the living body and we experiment with the higher frequency ultrasonic waves than 1.0 MHz ultrasonic waves.

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