MICROWAVE RADIOMETRIC DETECTION OF THERMAL ASYMMETRY OF VARICOCELE

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Abstract

Varicocele, a varicose enlargement of the veins in the spermatic cord, is found in 21-39% of men being evaluated for infertility. Thermometric detection of this condition was attempted by microwave radiometry as well as by contact thermometry using thermistor probes. The inguinal and scrotal regions of 44 male subjects and inguinal regions of 11 female subjects were studied. Substantially different thermal patterns were obtained by thermistors (surface temperature) and microwave radiometry (subsurface temperature). There was a correlation between left scrotal varicocele and a temperature elevation of the left spermatic cord using microwave radiometry. This thermal defect appeared to be corrected following surgery.

Introduction

Varicocele is the varicose enlargement, elongation and tortuosity of the veins in the spermatic cord. This condition is found in about 30-40% of men being evaluated for infertility [1-4]. Its prevalence in the general population ranges 10-23% [5-9]. Insufficiency and/or lack of the valvular apparatus in the spermatic veins is one of the major causes of male infertility. Abnormal semen analysis with low sperm count, abnormal forms and poor motility are frequently found in patients with varicocele. Once varicoce is detected, surgical ligation of the spermatic vein results in improvement of the sperm count in 58-71% of the patients and restored fertility in 24-55% [10-16].

Diagnosis of varicocele is often made by physical examination (palpation). Additional techniques are also used. In 25% of men with abnormal spermiogram, no varicocele was palpable, but an incompetent spermatic vein could be demonstrated by spermatic venography [17]. Venography, however, is an invasive procedure. Additional techniques for detecting varicocele include doppler ultrasound and thermography

Elevated scrotal temperature is well documented in patients with varicocele and felt to be the cause of abnormal spermatogenesis. Surface thermograms, whether non-contact by infra-red scanners or contact by liquid crystal techniques, are limited by their very nature. Since they are only surface techniques, they are less likely to reflect true temperature changes because of heat losses by conduction, convection, and radiation. Attenuation of core temperature occurs as well because of over-lying muscle, fascia, fat and skin.

In an attempt to overcome some of the apparent inadequacies of surface thermography, we have used microwave radiometry, which is a subsurface temperature-sensing technique. Our study involved taking microwave radiometric temperature measurements on both the right and left side of the inguinal and genital areas, and calculating thermal asymmetry as left-side temperature minus right-side temperature. Unilateral varicoceles are most commonly found on the left side (80-98%) and rarely on the right side [5,10,11,18,19]. Bilateral varicoceles occur in up to 20% of cases, but since they often form by extension from the left, they are often asymmetric [20].

Materials and Methods

The microwave radiometer, designed and built by M/A-COM, INC., operates at 4750 MHz. The unit has previously been described in greater detail [21]. Briefly, this Dicke-switched unit has a temperature-compensated receiver antenna which is reasonably well matched over the frequency range of the radiometer. The return loss is normally better than 10 dB when held against the hand. Return loss of 10 dB corresponds to a transmission loss of 0.45 dB, or 90% power transmitted. The insertion loss of the antenna was obtained by measuring the total loss of two identical antennae in series; i.e., mated at the waveguide openings. Assuming the transitions to be equal in loss, it was determined that the insertion loss of the single antenna was approximately 0.3 dB. To reduce the physical size of the normal C-band waveguide, dielectric loading is employed. The dielectric used is aluminum oxide having a relative dielectric constant, ϵ_r, of 9.5. The

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0149-645X/85/0000-0071 $01.00 © 1985 IEEE

aperture measures 1.58 cm x 0.79 cm. The cutoff characteristics of the C-band waveguide are utilized, the waveguide forming the high pass filter to isolate the sensitive receiver from high level out-of-band signals, such as when used in conjunction with hyperthermia equipment, etc.

Our technique involved placement of a prewarmed antenna to the right forearm. This was our reference measurement. The antenna was then applied to the body surface in the inguinal and genital area corresponding with the internal inguinal ring, the external inguinal ring, the spermatic cord (supra-testicular), anterior mid-testicular area, and the inferior pole of the testes. Measurements taken at each point were made first on the right side, then on the corresponding anatomic point on the left. Upon collection of the data, the right forearm area was remeasured to determine the extent of thermal drift.

This technique was used in the evaluation of 44 male patients, divided into six groups and assigned as illustrated in **Table 1.**

Fertility was defined as a subject having fathered a child. Those men who had not fathered a child had a thorough urologic evaluation and semen analysis. Additionally, 11 females underwent inguinal thermography, this to demonstrate the validity of the technique. Since women do not have a high vascular structure similar to the spermatic cord, there should be no detectable thermal asymmetry. The technique in women involved right forearm reference measurement, followed by measurements of inguinal areas corresponding to the internal cord and external inguinal rings. The right forearm measurement was then retaken to measure for drift.

All subjects were examined by the same urologist who also placed the antenna with same orientation at the assigned anatomic points. The 4750 MHz radiometer was operated by the same radiation biophysicist.

In several male subjects, surface thermometric data were obtained using an Omega Model 5800 Digital Thermometer. A surface thermistor probe was placed on each anatomic site for at least one minute to insure thermal stability. The thermistor probe was affixed to a wooden tongue depressor to minimize heating of the probe by the urologist's hand. For each anatomic site, thermometric evaluation preceded the placement of the radiometer antenna.

Results

Thermographic results from microwave radiometry are shown in **Table 2.** In Group A, the thermal asymmetry (left-right) at each anatomic point was $< 0.1^{\circ}C$ and felt to be insignificant. In Group B, thermal asymmetry (ΔT) was $< 0.1^{\circ}C$ except at the level of the testes, where an asymmetry of $0.2^{\circ}C$ was noted. With only four subjects in this group, however, this difference is not significant when compared with Group A. In Group C, an infertile patient (but who had no palpable varicocele) had a higher left spermatic cord temperature ($\Delta T = 0.37^{\circ}C$); but testicular measurements indicated a warmer right side ($\Delta T = -0.33^{\circ}C$ for the inferior pole).

In Group D, there was a significant ($P < 0.05$) warming of the left spermatic cord ($\Delta T = 0.35^{\circ}C$) and left testicle ($\Delta T = 0.27^{\circ}C$) compared with Group A. Since Group D had palpable left varicoceles with abnormal sperm counts, the correlation of the elevated left-sided temperature with left-sided varicocele supports the rationale for this microwave technique.

Patients in Group E had their varicoceles previously repaired, thereby reducing the vascularity on the left side. In turn, the temperature of the left spermatic cord and left testicle in this group was lower (cooler) than that of the right side by about $0.2^{\circ}C$. Thus, it appears that surgery (left spermatic vein ligation) has corrected the thermal defect shown in Group D, where the left side was warmer than the right.

One subject with bilateral varicocele (Group F) demonstrated a ΔT of $0.10^{\circ}C$ in the spermatic cord and testicular areas. No conclusion can be drawn from this exam.

In the 11 female subjects, no significant ΔT was measured (see **Table 3**), supporting the method of measurement when compared with male anatomy and particularly with Group D subjects.

Four fertile male subjects without varicocele had thermal profiles obtained by both surface thermometry and microwave radiometry (see **Table 4**). There did not appear to be any consistent agreement between these two methods. The differences in thermal profiles between the two techniques may simply reflect the fact that microwave radiometry is a subsurface technique whereas the thermistor measures only surface temperature.

Conclusions

Microwave radiometry appears to be a promising technique for detecting scrotal varicocele. It is a noninvasive and easily repeatable test which carries no known risk to the patient. The fact that there is a left-sided temperature elevation of the spermatic cord and testicle of subjects with varicocele (**Table 4, Group D**) compared with subjects without varicocele (**Table 4, Group A**) is highly encouraging. Also encouraging is the reversal of this trend in men who have had surgical correction of this defect (**Table 4, Group E**).

Table 1. Diagnosis and Age Distribution in 44 Male Subjects Undergoing Microwave Thermographic Examination.

GROUP	NO. SUBJECTS	AGE, YEARS	DIAGNOSIS
A	15	28.9 ± 3.9	Fertile, no varicocele
B	4	30.3 ± 1.0	Fertile, left varicocele
C	1	34	Infertile, no detectable varicocele
D	17	30.4 ± 4.8	Infertile, detectable left varicocele
E	6	32.7 ± 5.6	Post internal spermatic vein ligation
F	1	30	Bilateral varicocele

Table 2. Thermal Asymmetry (Left-Right), ^{o}C, in 44 Male Subjects.

GROUP	INTERNAL RING	EXTERNAL RING	SPERMATIC CORD	TESTICLE	INFERIOR POLE
A	-0.03	-0.09	-0.02	-0.02	-0.08
B	+0.07	+0.07	+0.04	+0.20	-0.03
C	-0.09	+0.08	+0.37	-0.07	-0.33
D	-0.01	-0.08	+0.35	+0.27	+0.05
E	+0.03	+0.06	-0.15	-0.19	-0.13
F	+0.12	0.00	+0.10	+0.10	+0.03

Table 3. Thermal Asymmetry (Left-Right), ^{o}C, by Microwave Radiometry in Eleven Female Subjects

GROUP	NO. SUBJECTS	AGE, YEARS	INTERNAL RING	EXTERNAL RING
G	11	27.7 ± 8.9	+0.02	-0.09

Table 4. Thermal Asymmetry (Left-Right) by Surface Thermometry and Microwave Radiometry in Four Fertile Male Subjects Without Varicocele

ANATOMIC SITE	ΔT, ^{o}C, SURFACE THERMOGRAPHY				ΔT, ^{o}C, MICROWAVE RADIOMETRY			
Subject:	1	2	3	4	1	2	3	4
Internal Ring	0.0	+0.4	0.0	-0.3	-0.1	-0.1	+0.2	0.0
External Ring	-0.3	+0.4	+0.2	-0.2	0.0	+0.2	-0.1	-0.2
Spermatic Cord	-0.1	+0.6	+0.1	-0.2	-0.4	0.0	+0.6	-0.3
Testicle	+0.1	-0.9	-0.6	+0.8	+0.1	+0.4	-0.2	0.0
Inferior Pole	-0.1	-0.8	+0.7	0.0	-0.2	+0.4	+0.1	-0.2

On the other hand, the examinations using this prototype radiometer are time-consuming. Only one anatomic point at a time is measured, usually about 45-60 seconds per point. In no way can this test supplant the physical exam, doppler studies, or venogram. Rather, it is an additional test -- one which requires further investigation and correlation before replacing any of the standard diagnostic methods.

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