Scrotal Infrared Digital Thermography for Detection of Subclinical Varicocele

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SUMMARY

Varicocele is the condition of abnormal venous dilatation of the pampiniform plexus and scrotal veins with blood reflux. In the literature the association of varicocele with male infertility risk has been described: venous reflux and the following scrotal thermal impairment have a deteriorating effect on spermatogenesis, even when assessed in asymptomatic subjects. Therefore a correct and early diagnosis of varicocele is mandatory. The aim of this study is to emphasize the diagnostic value of scrotal thermography in the investigation of varicocele combined with Color Doppler Ultrasound (CDU), considered the "gold standard" diagnostic tool thanks to its feasibility for measuring venous vessel size and blood flow parameters. 51 young asymptomatic volunteers (age range 18-36 years) underwent clinical examination, scrotal thermography and CDU, after providing informed written consent. Sarteschi classification was used for CDU evaluation. Among subjects, 21 (21/51, 40%) had left unilateral varicocele, detected using CDU; 21% (11/51) presented varicocele grade II, 11% (6/51) grade III and 8% (4/51) grade IV. Scrotal thermography documented an increased temperature and faster recovery of the left hemiscrotum in the same ones; a basal testicular temperature greater than 32°C and basal pampiniform plexus temperature greater than 34°C were considered warning values. Moreover thermal impairment of the left pampiniform plexus was assessed in other four subjects, whose CDU exam showed a higher vessel size (≥ 3 mm) with normal blood flow parameters. Clinical examination, affected by a low sensibility and specificity, showed the presence of left varicocele in only 12 volunteers (12/51, 24%). Our experience confirms that scrotal thermography is a feasible and low cost diagnostic tool for varicocele. Even if CDU remains the method as a reference, thanks to its high sensitivity, we suggest the use of scrotal thermography in screening programme in the assessment of subclinical varicocele.

1. INTRODUCTION

Varicocele is characterized by abnormal dilation and tortuosity of the pampiniform plexus secondary to a defect in the venous renospermatic system. The disorder is due to the blood flow inversion within the internal spermatic vein, which drains into the renal vein on the left side and directly into the inferior vena cava on the right side (1). Its incidence in young healthy male individuals is known to be 8-23%, with the left side being affected in 70-100% of cases and the right side in only 0-9% of cases; it is bilateral in 0-23% of cases (3).

Symptomatic varicocele is rare: it could cause testicular pain and discomfort.

Primary varicocele (idiopathic) could be related to valve incompetence, to retroperitoneal location of the internal spermatic vein (absence of contiguous muscles improving centripetal blood flow), to renal-vein abnormalities (e.g. "nutcracker syndrome", retroaortic left renal vein) and to vessel wall features. Secondary varicocele can be due to several pathological conditions (e.g. pelvic, abdominal and renal expansile processes, lymphomas, cecum cancer, hydronephrosis, hydroureter, pseudoaneurysm, splenorenal shunt due to portal hypertension).

Varicocele is potentially a progressive condition that may affect male fertility. Its prevalence in infertile men is about 30-40% (9). The most important factor is the venous reflux into the pampiniform plexus and the following scrotal thermal impairment and testicular tissue hypoxia which seem to have a deteriorating effect on spermatogenesis, even when assessed in asymptomatic subjects. Therefore a correct and early diagnosis of varicocele is mandatory.

Currently methods for diagnostic assessment of varicocele are a physical examination and Ultrasonography (US) and unenhanced Color Doppler Ultrasound (CDU), considered "gold standard" tools in the diagnosis and staging of varicocele (4, 10).
Thermography is a diagnostic method to record maximum and minimum temperatures across the skin surface of a select area using a highly sensitive infrared camera: therefore scrotal hyperthermia is evaluated through the measurement of the scrotal cutaneous temperature by means of thermal infrared imaging (2, 5, 6, 7, 8).
The aim of this study is to emphasize the diagnostic value of scrotal thermography in the investigation of varicocele combined with Ultrasonography/Color Doppler Ultrasound (US/CDU), especially in the assessment of subclinical one.

2. METHODS

Between April 2011 to date, 51 asymptomatic volunteers (age range 18-36 years), participating in a screening of young men reproductive diseases, underwent clinical examination, scrotal thermography and US/CDU, after providing informed written consent. No one had recently referred testicular inflammatory or cutaneous layers diseases; four (4/51; 8%) were surgically treated for phimosis. Participants were excluded if they presented history of cardiovascular, or neurovascular disorders, hypertension, history of drug or alcohol abuse and any therapeutic treatment. Men suffering from hydrocele were excluded too.
All subjects underwent clinical examination, US/CDU imaging, and infrared thermal thermography. US/CDU was performed with an Esaote, MyLab Xvision. They were first scanned during quite respiration and during Valsalva maneuver while supine, then while standing. For scrotal structural analysis, B-mode US with a high resolution and linear-array transducer with a frequency of 7.5 MHz was used. Bilateral transverse and longitudinal slices of the scrotum are performed to allow side-to-side comparison of their sizes and echo texture. CDU is established to illustrate scrotal macro and microcirculation, and to detect the varicocele grading based on retrograde blood flow during Valsalva maneuver and increased diameter of testicular veins. Sarteschi classification was used for CDU evaluation.
For each subject, the functional response to a mild cold challenge of scrotum was assessed by thermal infrared imaging (6, 7). All participants were asked to refrain from physical activities and intake of vasoactive substances for 2 hrs prior to the measurements. Before undergoing to measurements, the subjects took off pants and underwear leaving naked only the scrotum and the penis. Then they moved to the recording room which was set at standardized temperature (23 °*C*), humidity (50 - 60%), and without direct ventilation, in which they observed a 20-min acclimatization period prior to undergo the thermal imaging. The subjects comfortably sat during both acclimatization and measurement periods and were asked to keep their legs slightly divaricated in order to facilitate the thermal infrared imaging. The penis was gently attached by using medical tape to the lower abdomen in order to obtain clear thermal images of the scrotum Thermal infrared imaging was performed by means of a digital thermal camera (FLIR SC660, FlirSystems, Sweden), with a Focal Plane Array of 640 x 480 QWIP detectors, capable of collecting the thermal radiation in the 7-14 μm band, with a 0.02 s time resolution, and 0.04 *K* temperature sensitivity. Cutaneous emissivity was estimated as $\varepsilon \approx 0.98$. The thermal camera response was blackbody-calibrated to null noise-effects related to the sensor drift/shift dynamics and optical artifacts. Thermal images of the scrotum of each subject were recorded for 25 minutes, acquiring images every 30 seconds. Five thermal images were recorded before the cold stress to obtain the baseline of scrotum temperature. Each image series was corrected for motion artifacts by means of a contour alignment algorithm. The cold stress was achieved by applying a dry patch - maintained at 10° *C* - to the scrotum for two minutes. The penis was protected from the cold stress by avoiding any possible contact with the cooling patch which was shaped to be in contact with the scrotum only. Re-warming curves were obtained separately for each of the two hemiscrota, by averaging the temperature of the pixels within the cutaneous projection of the testis.
The basal prestress temperature and the recovery time constant τ at the level of the pampiniform plexus and of the testicles were evaluated on each hemiscrotum. A basal testicular temperature greater than 32°C and basal pampiniform plexus temperature greater than 34°C were considered warning values (2). Temperature differences among testicles (ΔT_t) or pampiniform plexus ΔT_p temperature greater than 1.0°C were also considered warning values, as were $\Delta\tau_p$ and $\Delta\tau_t$ values longer than 1.5 minutes (Merla 2002).

3. RESULTS

At a physical examination, the presence of left varicocele was evidenced in 12 volunteers (12/51, 24%). At CDU, among subjects, 21 (21/51, 40%) had left unilateral varicocele; 21% (11/51) presented varicocele grade II, 11% (6/51) grade III and 8% (4/51) grade IV. In all 21 patients diameter of pampiniform veins were larger than 2-3 mm, with positive reflux longer than 3 s during Valsalva maneuver. No one had right or bilateral varicocele.

Fig. 1 - Example of scrotal hyperthermia secondary to III grade left varicocele.

Values for ΔT_p and the $\Delta \tau_p$ were higher than the warning thresholds in 25 of the 51 men.
CDU imaging and clinical examination classification confirmed the presence of grade 2-4 varicocele in these subjects.

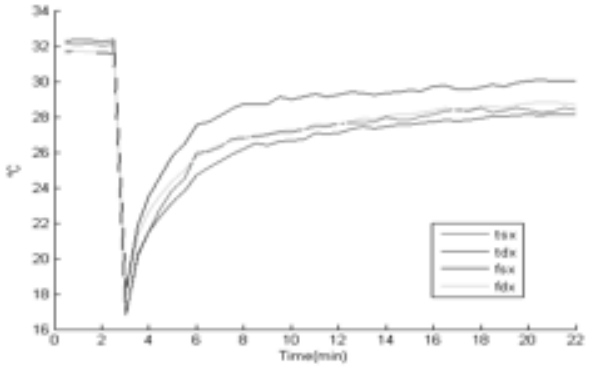

Fig. 2 - Example of scrotal rewarming curves after functional thermal stimulation.

Thermal imaging yielded four false-positive, which were considered as early stage (grade 1 varicocele) at CDU investigation and no false-negative results.
The sensitivity and specificity of thermal imaging were 100% and 92%, respectively. Analysis of variance showed strong statistical significance of basal values and rewarming values associated with scrotal asymmetry. The sensitivity and specificity of the combined thermal imaging and CDU were 100%.

4. CONCLUSIONS

Our data demonstrate that an abnormal change in the temperature of the testicles and pampiniform plexus may indicate varicocele. Furthermore, impaired thermoregulation is associated with varicocele-induced alteration of blood flow (5). Time to recovery of pre-stress temperature in the testicles and pampiniform plexus appears to assist in classification of the disease. Cold stress enhances the altered thermal properties of the affected hemiscrotum and may provide useful information in future studies of scrotum thermoregulation, varicocele, and fertility.
Findings on thermal imaging, clinical examination, and echo color Doppler imaging were very consistent. Infrared functional imaging consistently and accurately indicated that 25 men had no symptomatic varicocele. No control on spermatic activity was done, because we aimed to assess whether impaired thermoregulation was associated with varicocele.
According to our experience, clinical examination is affected by low sensibility and specificity. Therefore, clinical examination alone cannot adequately diagnose small and subclinical varicocele. US/CDU represent the "gold standard" method and a well tolerated imaging modality for evaluation of varicocele; nevertheless one of its disadvantages is that it chiefly depends on experience and interpretation of examiners.
Despite its low specificity and inability to distinguish between varicocele and other scrotal pathology, we emphasize that infrared digital thermography is a feasible and low cost diagnostic tool for varicocele; thanks to its high sensitivity, we suggest the use of scrotal thermography in screening programme in the assessment of subclinical varicocele.

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