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● *Original Contribution*

DOPPLER CHARACTERISTICS OF CAVERNOSAL–SPONGIOSAL COMMUNICATIONS IN PATIENTS WITH ERECTILE DYSFUNCTION

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Abstract—The goal of this work was to characterize the blood flow in cavernosal–spongiosal communications (CSCs) in patients with erectile dysfunction using color Doppler ultrasound. Peak systolic velocity was measured in the CSCs, cavernosal artery and urethral artery in 72 erectile dysfunction patients of the Han ethnic group in southern China. Blood in the CSCs was observed to flow from the cavernosal artery to the urethral artery in all except 5 patients with arteriogenic insufficiency whose blood flow was bidirectional. Peak systolic velocity in erectile dysfunction patients with normal vascular function or veno-occlusive dysfunction was significantly lower in the CSCs than in the cavernosal artery ($p < 0.01$), but significantly higher than in the urethral artery ($p < 0.05$). Peak systolic velocities in CSCs in patients with arteriogenic insufficiency were significantly lower than those in the cavernosal ($p < 0.01$) and urethral ($p < 0.01$) arteries. The direction of blood flow in the CSCs is determined by the pressure gradient between the cavernosal and urethral arteries. (E-mail: marcher126@126.com) © **2015 World Federation for Ultrasound in Medicine & Biology.**

Key Words: **Erectile dysfunction, Color Doppler ultrasound, Cavernosal–spongiosal communications, Cavernosal artery, Urethral artery.**

INTRODUCTION

Erectile dysfunction (ED) is defined as the consistent inability to attain or maintain a penile erection of sufficient quality to permit satisfactory sexual intercourse (NIH Consensus Development Panel on Impotence 1993). The prevalence of this disorder increases with age. In a cross-sectional study in the United States (Feldman et al. 1994), the prevalence of ED was 22% among men between the ages of 40 and 49 y and increased to 49% among men between the ages of 70 and 79 y. In China, the prevalence of ED was reported to be 26% among men between 41 and 50 y and 65% among men aged 61–70 y (Bai et al. 2004). It has been estimated that the worldwide prevalence of ED will increase by 111% in 2025 compared with 1995 (Ayta et al. 1999).

The cavernosal artery (CA) supplies the corpora cavernosa *via* multiple helicine arteries (HAs), and the urethral artery (UA) runs forward along the dorsal side of the tunica albuginea of the corpus spongiosum and provides blood supply to it and the urethra. There are anastomoses between the CA and UA (Diallo et al. 2013), forming a network called cavernosal–spongiosal communications (CSCs). The CSCs are anatomically different from the HAs, although both are branches of the CA. The HAs further give rise to multiple arterioles entering into the corpora cavernosum, whereas the CSCs run vertically toward the ventral side of the penis and enter the corpus spongiosum after passing through the tunica albuginea (Wagner et al. 1982). The CSCs, with a diameter of approximately 0.1–0.4 mm, were thought to carry blood from the CA to the UA under normal conditions, but the blood flow can be reversed during intra-urethral alprostadil-induced erection (Droupy et al. 1999). However, the exact physiologic role of the CSCs connecting two erectile corpora with very different pressure ratings during erection remains unclear.

Color Doppler ultrasound (CDUS) evaluation plays a significant role in determining the cause of ED (Golijanin et al. 2007). CDUS is an objective and reliable diagnostic method for monitoring penile hemodynamic

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changes (Patel et al. 2012; Sikka et al. 2013), providing real-time information on penile arterial inflow and venous outflow (Golijanin et al. 2007). Doppler features of the CSCs have been described in patients with different diseases (Bertolotto et al. 2002a, 2002b); however, their roles in penile erection in patients with ED are unclear.

In the present study, we used CDUS to examine blood flow in the CSCs during the process of erection, before and after drug intervention, and its relationship to the CA and UA in patients with ED. Our goal was to characterize blood flow in the CSCs in patients with ED.

METHODS

Enrollment of participants

The study population was selected from patients who visited our hospital for erectile problems from August 2011 to July 2013. All patients were of Han ethnicity and from Guangdong Province, China. The criteria used to enroll participants were: (i) inability to obtain or maintain sufficient penile erection to achieve intercourse for at least 6 mo before the study; (ii) age >25 y; and (iii) an International Index of Erectile Function 5 score <21. Patients who had a history of (i) traumatic penile injury, (ii) spinal injury or (iii) mental disorder or (iv) who had received treatment for ED were excluded. Initially, a total of 81 patients with ED were included in the study. All participants provided written informed content, and the study was approved by the ethics committee of our institute.

Assessment of penile erection

All patients were evaluated for erectile function through their detailed history, physical examination, whole blood counts, blood levels of sex hormones (*i.e.*, testosterone, luteinizing hormone and follicle-stimulating hormone) and International Index of Erectile Function 5 questionnaires. All participants had normal blood levels of sex hormones.

CDUS of patients with ED

CDUS was performed by an experienced sonographer who has been performing CDUS on patients with ED for more than 10 y. The sonographer was blind to the patients' histories. IU22 (Philips, Eindhoven, Netherlands) or Logiq E9 (General Electric, Orange, CA, USA) CDUS units were used for all patients. The frequency of the transducer was 5–15 MHz. Imaging parameters were optimized to reach the highest spatial resolution and color sensitivity for slow flows. Color Doppler study and spectral analysis started with slow flow settings, which were tuned during the examination on minimal pulse repetition frequency values. Spectral interrogations of the CSCs, CA and UA were obtained with the help of color Doppler signal. The angle between the transducer and blood flow was ≤60° and was constantly adjusted by manually correcting the cursor and steering. Then peak systolic velocity (PSV) and end diastolic velocity (EDV) were measured. The CA was measured at the junction of the penile shaft and the scrotum, and the CSCs and UA were measured in the middle of blood vessels with good ultrasound signals for blood flow at the root of the penis. CSCs were measured at the same position on blood vessels before and after penile erection. The spectrum was considered valid if Doppler displayed five to seven consecutive identical images; the absolute value was recorded from one selected image.

Patients in the supine position were examined with CDUS in a warm and quiet private room. With the penis gently placed toward the abdomen and the transducer placed at the ventral surface of the root of the penis, the right CSCs were observed first and then the direction of the blood flow in the flaccid penis was recorded. Ten micrograms of prostaglandin E1 (PG-1) was injected into the left corpus cavernosum with 1 min of local gentle massage to help diffuse the drug into the tissues. The patient was instructed to stimulate his penis manually for 5 min and was then examined 10, 15, 20 and 25 min after injection. PSV and EDV were measured in the CA, CSCs and UA. If the patient reported that the erection was softer than the best spontaneous erection obtained during sexual activity, insufficient smooth muscle relaxation was considered, and a second dose of 10 μg of PG-1 was injected. All five patients obtained satisfactory erection after the second injection of PG-1. One patient experienced priapism for more than 8 h after the first injection of PG-1. After emergent aspiration of blood with irrigation of the corpora cavernosa, in combination with intra-cavernous adrenalin injection, the symptom was resolved.

Patients with a PSV >30 cm/s and diastolic reversal flow in the CA are considered to have normal-vascular-function ED or non-vascular function-based ED (Lee et al. 1993). Patients were diagnosed with arteriogenic insufficiency (AI) if their PSV in the CA was <25 cm/s after injection of the vasoactive drug, regardless of the direction of blood flow during diastole (Chiou et al. 1998; Fitzgerald et al. 1992). Veno-occlusive dysfunction (VOD) was indicated if the patient had a PSV >30 cm/s and an EDV >5 cm/s in the CA (Lue et al. 1985). Patients with a PSV between 25 and 30 cm/s or an EDV between 0 and 5 cm/s in the CA after intra-cavernosal injection of PG-1 were excluded from the study.

Data analysis

Data were analyzed using SPSS 12.0 (SPSS, Chicago, IL, USA). The data are presented as means ± standard errors (SE). Comparisons of mean PSVs in the CSCs,