Intracompartmental Pressure as a Predictor of Intratesticular Blood Flow: A Rat Model

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Abbreviations and Acronyms

CF = color flow

ICP = intracompartmental pressure

I/R = ischemic reperfusion

PW = pulse wave

SFP = stop flow pressure

Study received institutional animal care and use committee approval.

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Purpose: We identified an intratesticular pressure at which vascular flow would cease in a testicular compartment syndrome model, defining a critical vascular stop flow pressure.

Materials and Methods: A total of 52 male Sprague Dawley® rats were used for the study. The testicle of each rat was delivered from the scrotum and size measurements were taken. An intracompartment pressure monitor needle was inserted into the testis to record basal intratesticular pressure. The monitor needle remained in the testicle for the duration of the procedure. Vascular flow within the testis was measured using a variable frequency linear ultrasound transducer with color flow and pulse wave Doppler modalities. Saline was infused through the compartment monitor in 5 mm Hg increments via a pressure infusion pump. Following each 5 mm Hg increase intratesticular vascular blood flow and velocities were recorded using color flow and pulse wave, respectively. Data collection proceeded until color flow images indicated a complete absence of flow within the testis.

Results: Using a paired t-test ($p < 0.0001$), mean color flow stop flow pressure was 52.17 mm Hg (95% CI 49.57–54.77) and pulse wave stop flow pressure was 36.34 mm Hg (95% CI 33.90–38.77). Regression analysis of pulse wave vs color flow showed a slope of 0.6960 ± 0.09112, a y-intercept of 0.02427 ± 4.824 and an x-intercept of -0.03486.

Conclusions: This is the first known study to characterize a stop flow pressure within the testicular parenchyma resulting from an increased intracompartmental pressure. Due to probe sensitivity limitations, color flow appears to provide the most precise mean pressure of occlusion of 52.17 mm Hg.

Key Words: compartment syndromes, perfusion, pressure, spermatic cord torsion, testis

TESTICULAR torsion is a surgical emergency occurring in 8.6 per 100,000 males 10 to 19 years old,[1] affecting 1 in 160 males by age 25.[2] Torsion occurs in this age group due to a lack of the caudoposterior anchoring of the testis within the scrotum. This condition results in the tunica vaginalis completely encircling the testicle, permitting the testis to orient itself around the transverse axis rather than the cephalocaudal axis. This "bell clapper" deformity allows the testis to freely rotate within the

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tunica vaginalis.[3] Torsion of the spermatic cord results in venous congestion and the loss of testicular arterial blood flow, causing testicular ischemia. This state may result in irreversible cell death, and testicular atrophy and loss.[4]

On spontaneous or manual detorsion of the spermatic cord reinstitution of arterial blood flow may occur to varying degrees, bringing the prediction of ultimate testicular viability into question. The testicle may also experience ischemic reperfusion injury, which may further damage testicular tissue.[5] I/R injury initiates a pathophysiological cascade, leading to extravascular fluid compartmentalization within the testis.[6] Because the tunica albuginea is an inelastic fascia, the edema and inflammation of testicular tissue may lead to increased intratesticular pressure, resulting in a compartment syndrome and subsequent parenchymal damage.[7] Identification of a testicular compartment syndrome is often guided by vague subjective characteristics following testicular detorsion, such as appearance, color and firmness of the testis.

Using a rat model, we measured testicular intraparenchymal blood flow and velocity as a function of increasing tunica albuginea intracapsular testicular pressure to simulate an I/R injury and compartment syndrome. Our goal was to identify an intracapsular testicular pressure at which vascular flow would cease, defining a critical vascular stop flow pressure.

MATERIALS AND METHODS

Animal care and use committee approval from Michigan State University was obtained before collection of all data. A total of 52 male Sprague Dawley rats were used for the study. Rats were acclimated to their environments for a minimum of 3 days. Each rat was placed in an enclosed container and anesthetized with isoflurane using a precision vaporizer. The anesthetized rat was removed and placed supine, and an incision was made longitudinally along the median raphe to open the scrotum. The testicle of each rat was delivered from the scrotum. The tunica vaginalis was opened and placed onto a clay receptacle, where size measurements were made. Testicular volumes were calculated using the formula described by Cimador et al.[8] The experimental procedure was performed on the right and then the left testicle.

A Logiq 9 ultrasound unit with triplex Doppler (GE® Healthcare Life Sciences) was used for testicular imaging. Flow measurements of the testis were collected using a variable frequency linear transducer (GE model M12L ultrasound probe) with color flow and pulse wave modalities. CF images were acquired at 7.5 MHz and PW images were acquired at 5.6 MHz. For both types of imaging the pulse repetition frequency was adjusted to optimally display flow information, and gain was increased until noise became evident.

Preliminary scanning of the testis allowed for identification of an intraparenchymal artery, as confirmed in the coronal and sagittal planes. Once the target vessel was localized, the probe was clamped to a ring stand to hold its position constant. A Stryker® Intra-Compartmental Pressure Monitor (model 295) with an 18-gauge needle was then inserted into the caudal most margin of the testis to a depth of 5 mm, and basal intracompartmental pressure was recorded (fig. 1). The needle was left in the testicle at this position for the duration of the procedure. The target vessel was then once again reconfirmed (fig. 2) and the ultrasound probe was readjusted as necessary.

Following baseline pressure and velocity measurements saline infusion through the compartment monitor via an IVAC® pressure infusion pump was performed at an infusion rate of 20 μl per minute. The testicular intracompartmental pressure was increased in 5 mm Hg

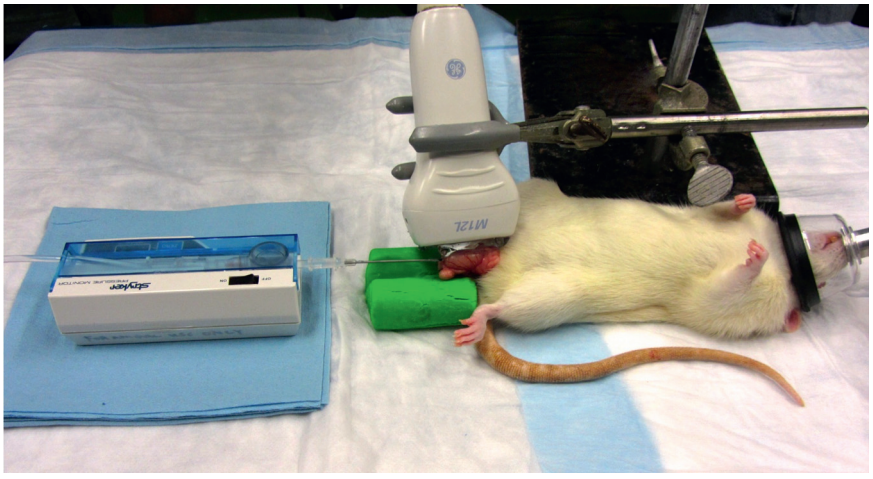

Figure 1. Rat is positioned for saline infusion with needle inserted 5 mm into testis and 12 to 14 Hz Doppler probe positioned over target vessel.