

Vascular response to ischemia in the feet of falanga torture victims and normal controls

Color and spectral Doppler findings

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Abstract

Objective: To investigate whether signs of chronic compartment syndrome could be found in plantar muscles of falanga torture victims with painful feet and impaired gait. The hypothesis was that the muscular vascular response to two minutes ischemia would be decreased in torture victims compared to controls. On color Doppler this would be seen as less color after ischemia and on spectral Doppler as elevated resistive index (RI).

Methods: Ten male torture victims from the Middle East and nine age, sex and ethnically matched controls underwent Doppler examination of the abductor hallucis and flexor digitorum brevis muscles before and after two minutes ischemia induced with a pressure cuff over the malleoli. The color Doppler findings were quantified with the color fraction (CF) before and after ischemia. On spectral Doppler the resistive index was measured once before and three consecutive times after ischemia.

Results: Both torture victims and controls responded to ischemia with an increased CF. There

was no difference between torture victims and controls. With spectral Doppler all subjects had an RI of 1.0 before ischemia. After ischemia, in nearly all subjects and all muscles the first RI was lowest, the second was higher and the third was highest indicating that the response to ischemia was disappearing as measurements were made. There was a trend that the first RI was higher in torture victims than in controls.

Discussion: The study was not able to confirm the presence of chronic compartment syndrome. However, the trend in RI still supports the hypothesis. The negative findings may be due to inadequate design where the CF and RI were measured in one setting, perhaps resulting in both methods being applied imperfectly. The response to ischemia seems short-lived and we suggest that the Doppler methods may be re-evaluated with separate ischemic phases for CF and RI.

Keywords: torture, falanga, chronic compartment syndrome, ultrasound, Doppler, resistive index

Introduction

Falanga is a torture method involving systematically repeated application of blunt trauma to the soles of the feet. It is still widely practiced especially in the Middle East.¹ The torture victims are beaten on the soles of their feet with rattle butts, wooden poles, iron rods, cables, or sticks. In addition, the torture victims may be forced to

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walk, run or jump with bare feet on rough surfaces to increase the pain.

Years after falanga, chronic pain in the feet and lower legs is common.² Deep, dull and cramping pain in the feet and lower legs may intensify with weight bearing and walking. Also, a sensation of burning, stinging pain in the soles is frequently reported.³ The torture victims typically have impaired gait.

Some authors suggest that part of the pain mechanism may be the development of a chronic compartment syndrome in the tight muscle compartments in the planta.⁴ The theory is that when the need for oxygenated blood increases (walking, weight bearing) the muscles cannot expand adequately within their compartments to allow sufficient blood flow, thus leading to ischemic pain.⁵

We wished to explore this mechanism non-invasively with Doppler ultrasound. With color Doppler, resting muscles have detectable perfusion seen as color foci blinking with the heart cycle. When muscles contract, oxygen is spent and in the following relaxation a transient increased perfusion is seen with color Doppler. Furthermore, in resting muscles the peripheral vascular resistance is high because the need for blood flow is low and consequently blood flow in the diastole is low or absent. The peripheral vascular resistance may be quantified with spectral Doppler using the resistive index (RI), which is defined as "peak systolic velocity – enddiastolic velocity"/"peak systolic velocity".⁶ RI has been widely applied in obstetrics and nephrology where an increased peripheral vascular resistance (increased RI) denotes pathology as well as in rheumatology where a decreased vascular resistance (decreased RI) indicates inflammation.⁷

Because the vascular response to exercise in muscles is transient, we needed to induce the muscle stimulus on the supine subject

(so that we could examine him immediately after the stimulus). Furthermore, we wished a standardized stimulus and therefore induced the muscular vascular response with a period of ischemia instead of muscle exercise.

Our hypotheses were that torture victims had increased stiffness of the muscle compartments and that the vascular response to ischemia would be reduced compared to normals. On color Doppler this would be seen as less color in a transverse scan of the muscle and with spectral Doppler there would be reduced diastolic flow resulting in an increased resistive index (RI).

Material and methods

Participants: Thirty torture victims who had previously completed an interdisciplinary rehabilitation program at the Rehabilitation and Research Centre for Torture Victims in Copenhagen were invited via mail to participate in the study. Inclusion criteria were: exposure to falanga and over 18 years of age. Eighteen of the thirty torture victims came to individual information meetings. Of these 18, seven were not included: four did not want to participate, one had a psychological impairment and one had not been subjected to falanga. Thus, 11 torture victims were scheduled for ultrasound examination.

Eleven age, sex and ethnic-matched controls with no history of torture were recruited from first generation immigrants in the Arab community of Copenhagen.

All participants were male. The mean age and range was 43 (34-54) for the torture victims and 40 (30-52) for the controls.

Ultrasound: The ultrasound examination was carried out with a Siemens Acuson Sequoia equipped with a linear array transducer with a center frequency of 14 MHz. Before scanning, the participants sat with their feet in lukewarm water in order to

improve subsequent sound propagation through the thick plantar stratum corneum. For scanning, the participants were placed supine with their feet hanging freely from a pillow behind the distal lower legs. The participants remained in this position throughout the procedures.

Color Doppler: Color and not power Doppler was used because it is more sensitive on the Sequoia machine. The system was optimized for low velocity flow with a Doppler frequency of 7 MHz, lowest pulse repetition frequency and lowest wall filter, and with gain just below the noise threshold. The system then had highest sensitivity for detection of any flow (slow and fast). Blooming artifacts (color bleeding outside the boundaries of the vessels) were accepted as a systematic error. The color Doppler settings were the same for all subjects. The color Doppler findings were stored digitally by activating an automatic four seconds cine-loop recording.

Spectral Doppler: The spectral Doppler gate was placed over a vessel visualized with color Doppler. An image with the spectral Doppler trace was stored digitally.

Procedure

Pre-ischemia: The right abductor hallucis muscle was scanned in transverse with color Doppler. The scan plane with most Doppler activity was marked on the skin with dye. A four seconds cine-loop and a subsequent image with spectral Doppler trace were stored. This procedure was repeated on the right flexor digitorum brevis muscle as well as the same two muscles on the left side.

Ischemia: Ischemia was induced with a blood pressure cuff placed just above the malleoli. The cuff was inflated to 200 mm Hg and with color Doppler it was confirmed that no perfusion could be detected distally to the cuff. The pressure was maintained for two minutes.

Post-ischemia: The pre-ischemia scanning position was re-established guided by the dye markings on the skin. The cuff was then deflated and as the first color Doppler signals inside the muscle were seen, the following four seconds were stored. An additional four seconds cine-loop was stored if the first contained too many motion artifacts or if the color Doppler activity continued to increase. Three different vessels (if possible) were then investigated with spectral Doppler and the images with the Doppler traces were stored.

The ischemia and subsequent post-ischemia procedures were performed separately on the four muscles. Thus each subject experienced four ischemic episodes.

Image evaluation

Cine-loops: From each cine-loop the image with maximum color Doppler activity and the image with minimum color Doppler activity were exported as jpeg-files. Each image was imported into the program DataPro (Courtaboef, France) where a trace was made around the muscle. The program then reported the color fraction (CF) which was the number of color pixels inside the trace divided by the total number of pixels inside the trace (Figure 1).

Spectral Doppler traces: The spectral Doppler traces were reviewed in the program LogiqWorks (General electric, Milwaukee, WI, USA). On each Doppler trace, the maximum systolic velocity and the enddiastolic velocities were measured and the resistive index was calculated.⁶ The resistive index was (maximum systolic velocity – enddiastolic velocity)/maximum systolic velocity (Figure 2). If no spectral Doppler trace could be recorded (absence of detectable arteries), the RI was defined to be 1.0, which is the normal value in resting musculoskeletal tissues.

Thus, from each subject the following 32

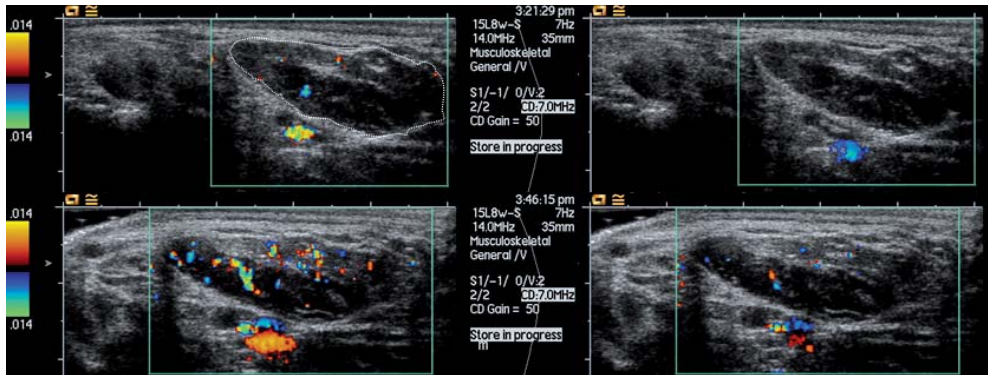


Figure 1: Color fraction before and after ischemia. The images are transverse scans of the left abductor hallucis muscle in a control subject. Top row shows the maximum and minimum color Doppler activity before ischemia. The muscle is outlined with a dotted trace and the color fraction (CF) is 3%. In the diastole there was no Doppler activity and the CF was 0%. The bottom row shows the corresponding findings after 2 minutes ischemia. The maximum CF (left) is 20% and the minimum CF (right) is 4%.

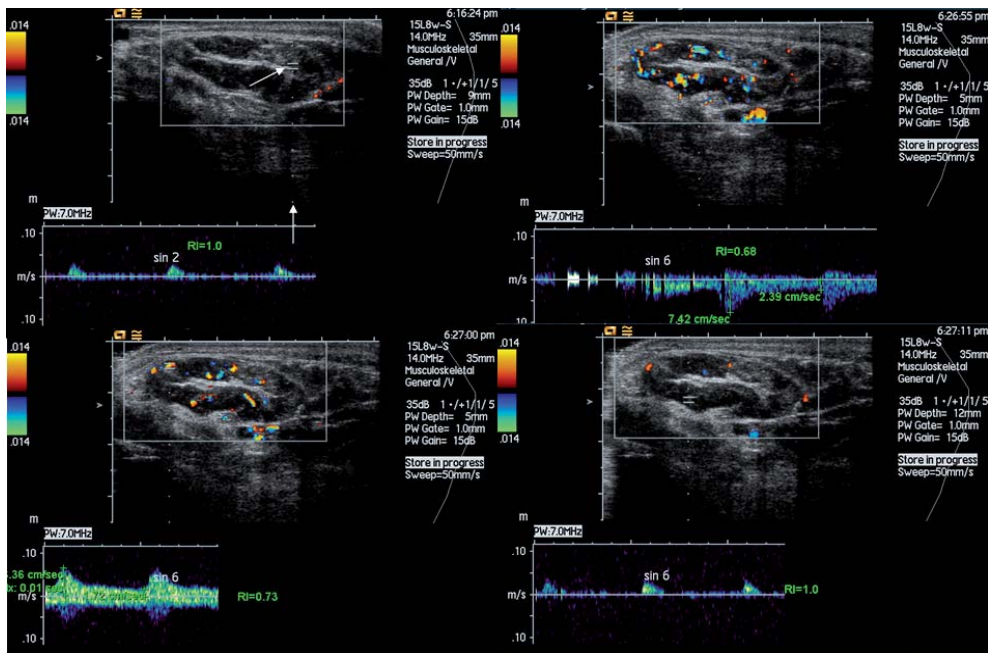


Figure 2: Resistive index (RI) before and after ischemia. The images are transverse scans of the left abductor hallucis muscle in a control subject. They are triplex scans meaning that grey-scale ultrasound is combined with color Doppler and spectral Doppler. Color Doppler is used to identify the vessels and guide the positioning of the Doppler line (vertical arrow) and the Doppler gate (oblique arrow). The spectral Doppler measurements are performed inside the gate (between the two horizontal lines). In the bottom of each image the spectral Doppler trace is seen. Top left is before ischemia. The Doppler trace shows only systolic flow and the RI is 1.0. Top right is the first RI-measurement after ischemia. Flow is seen throughout the cardiac cycle. The peak systolic and enddiastolic flows have been measured and the RI is 0.68. Bottom left is the second RI-measurement which is similar to the first. RI is 0.73. Bottom right is the third RI-measurement where the preischemic conditions seem reestablished. RI is again 1.0.

values were recorded from left and right abductor hallucis and flexor digitorum brevis muscles:

CF: Pre-ischemia maximum and minimum, post-ischemia maximum and minimum.

RI: Pre-ischemia RI; first, second, and third post-ischemia RI.

Originally, it was planned also to investigate selected muscles of the lower leg after ischemia induced by a pressure cuff just above the knee. This was aborted because cuff insufflations in this position could not be tolerated by the first participants (torture victims).

Statistics

Groups stratified by muscles and pooled muscles were compared with a two-sample t-test with pooled variance. Level of significance was 5%.

Ethics

Each participant received oral and written information about the study in Arabic and in Danish. The participants also received guidelines concerning participation in medical research issued by the Danish Ethical Committee. Written consent was then signed and an appointment for ultrasound examination given. The study was registered with the Regional Committee for Ethics in Medical Science in Copenhagen and with the Danish Data Protection Agency.

Results

Of the 11 torture victims, one found the pressure cuff to be too uncomfortable and had to be excluded leaving 10 torture victims who completed the study. Of the 11 controls, one found the pressure cuff to too uncomfortable and one revealed that he had actually had falanga torture. Both these

controls were excluded leaving nine who completed the study. The 10 torture victims were seven from Iraq and three from Iran. The nine controls were seven from Iraq, one from Tunisia, and one from Syria.

The recruitment and clinical findings of the study group has previously been reported.³ All torture victims had painful foot dysfunction and impaired gait as falanga sequelae.

Color fraction: The two minutes ischemia resulted in an increase in color Doppler activity in all four muscles in nearly all torture victims and controls. In four torture victims and two controls ischemia resulted in a fall in CF at a single site – from 9, 8, 2, 2, 17 and 11% to 4, 5, 1, 0, 2 and 10%, respectively. In one torture victim and one control a single site showed no change – 0 and 4%, respectively. Maximum values, minimum values, and averages of maximum and minimum both before and after ischemia were analyzed and no differences between torture victims and controls could be detected. For illustration the mean and range for the maximum values are shown in Table 1.

Resistive index: Before ischemia it was possible to measure RI at 72 of 76 sites (four muscles in 19 subjects) and it was 1.0 in all cases. The four sites where RI was defined as 1.0 represented four torture victims. After ischemia, it was possible to measure three RI-values in 53% and 47%, only two RI-values in 35% and 33%, only one RI-value in 10% and 14%, and no RI-value (defined as 1.0) in 5% and 6% of the 40 and 36 sites in torture victims and controls, respectively (Table 2).

The abductor muscles were more vascular than the flexor muscles and it was possible to measure more RI-values. The mean number of measured RI-values ranged from 2.6 to 2.9 in the abductor muscles and from 1.6 to 2.2 in the flexor muscles. There was

Table 1. Maximum color fractions before and after ischemia. Numbers are percentage color area inside transverse scan of the muscle, mean, (range).

Muscle	Torture victims		Controls	
	Before	After	Before	After
Right abductor	5.6 (1-10)	14.1 (4-38)	6.2 (1-13)	17.7 (4-31)
Left abductor	6.6 (4-19)	19.8 (4-39)	7.9 (3-17)	19.6 (2-38)
Right flexor	3.0 (0-9)	19.0 (0-51)	4.3 (2-7)	14.4 (2-32)
Left flexor	2.4 (0-8)	6.2 (1-11)	4.1 (2-9)	14.4 (3-32)

Table 2. Resistive index (RI) after ischemia. Numbers are mean, (range).

Muscle	Torture victims				Controls			
	1st RI	2nd RI	3rd RI	Number of RI	1st RI	2nd RI	3rd RI	Number of RI
Right abductor	0.86 (0.75-1.0)	0.95 (0.75-1.0)	0.93 (0.75-1.0)	2.9 (2-3)	0.75 (0.67-0.87)	0.76 (0.56-1.0)	0.93 (0.72-1.0)	2.8 (2-3)
Left abductor	0.80 (0.69-1.0)	0.82 (0.67-1.0)	0.91 (0.52-1.0)	2.6 (2-3)	0.77 (0.61-1.0)	0.84 (0.65-1.0)	0.89 (0.66-1.0)	2.6 (1-3)
Right flexor	0.95 (0.68-1.0)	0.97 (0.70-1.0)	1.0 (1.0-1.0)	1.7 (0-3)	0.85 (0.61-1.0)	0.92 (0.63-1.0)	1.0 (1.0-1.0)	1.6 (0-3)
Left flexor	0.84 (0.59-1.0)	0.94 (0.67-1.0)	0.97 (0.69-1.0)	2.2 (1-3)	0.94 (0.68-1.0)	0.95 (0.74-1.0)	1.0 (1.0-1.0)	2.0 (1-3)

no difference between torture victims and controls concerning number of RI-measurements. The abductor muscles had lower RI-values than the flexor muscles both in torture victims and controls.

Except for the right abductor muscle in the torture victims, the first RI measurement was the lowest, the second was higher and the third was highest indicating that the effect of ischemia was disappearing as the measurements were made. The first RI-measurements were lowest in the controls except for the left flexor muscle where the torture victims had the lowest value. The third RI-values were more or less identical in torture victims and controls.

Discussion

The results show very similar response to two minutes ischemia in the medial two

superficial muscles in the planta in torture victims and controls. Neither the absolute color fraction before and after ischemia nor the relative change could separate torture victims from controls. The RI-measurements showed a trend toward torture victims having a higher vascular resistance immediately after ischemia. This may support the theory of a relative closed compartment syndrome being part of sequelae to falanga torture.

The ultrasound scanning was in no way uncomfortable to the subjects since it only involved a light pressure to soles of the feet. The pressure cuff around the ankle was uncomfortable but was equally tolerated by victims and controls with only one in each group aborting the procedure.

We did not find any significant differences between victims and controls and this may be because we measured both the

development in CF and RI instead of aiming at one or the other. Directly after releasing the cuff pressure we spent time recording one or two 4 second cine-loops and thereby we have no data of the immediate RI-response. Our data suggest that the response is relatively short-lived and that controls may have a lower vascular resistance initially that increases to the level of the victims during the time it takes to make three RI-measurements. If we had focused solely on RI-measurements and not performed the CF-measurements we could have investigated this part of the response.

Also, the CF-measurements may be suboptimal. We focused on the immediate response and once a successful 4 seconds cine-loop showing Doppler activity that did not increase further had been recorded, we spent the remaining time recording three RI-values when possible. It may be that it would have been more fruitful to record one long cine-loop showing the full response where we would have been able to record time to peak as well as time to the return to pre-ischemia values. It has been reported that closed compartment syndrome patients have delayed peak and a prolonged response.⁸ Our results indicate that the victims may have a prolonged response. We measured more RI-values in the victims which may be because more vessels were available for a longer period of time. Furthermore, our results indicate that we may have measured RI-values as the response was disappearing in the controls seen as lower first RI-measurements and more or less identical third RI-measurements.

We were not successful in finding a diagnostic method to separate torture victims from normal controls. Nor were we successful in establishing presence of a relative closed compartment syndrome in falanga torture victims with painful feet and im-

paired gait. Our negative findings may, however, be due to inadequate design and we suggest further investigation of color/power Doppler and spectral Doppler response to ischemia where the two methods are tested separately. The method still has the potential to disclose important information and is relatively well tolerated by torture victims.

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