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Hemodynamic Effects of Experimental Testicular Torsion

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Summary. Experimental testicular torsion must be used for certain studies of clinical relevance, but most experimental models either do not provide hemodynamic alteration comparable to the clinical situation or cannot guarantee reproducibility. Using a rat model arterial perfusion and hemorrhagic infarction were correlated to the degree of both intra- and extravaginal testicular torsion. Arterial inflow was measured sequentially with radiolabelled microspheres, hemorrhagic infarction was judged by the increase of testicular weight. Maximal hemorrhagic infarction and reproducible values were found when the spermatic cord was twisted togehter with the tunica vaginalis for 360°–540°.

Key words: Testicular torsion, Rat, Hemodynamics, Hemorrhagic infarction, Radiolabelled microspheres.

The effects of anoxia on the ipsilateral and contralateral testis were subject of a variety of animal experiments, which usually were performed to elucidate problems related to torsion of the testis [7, 8, 9, 13].

Complete occlusion of the testicular artery or all testicular blood vessels results in complete ischemia over a definite period [6, 7]. This model is reproducible, but does not reflect the clinical situation.

Due to obstruction of the plexus pampiniformis, testicular torsion usually results in hemorrhagic infarction, the biological effect of this is not the same as that of ischemia alone [6]. With an increasing degree of torsion the testicular artery is finally obstructed thereby producing complete ischemia. The extent of hemorrhagic infarction and the incidence of ischemia in relation to the degree of torsion has not been reportet elsewhere. Hence the effect of an experimental testicular torsion on testicular hemodynamics cannot be predicted exactly. As reproducibility is the basis of any experiment, the following study was undertaken to obtain definite data.

Radiolabelled microspheres were used to assess changes in testicular perfusion after torsion. When injected intraarterially the microspheres are trapped completely at the level of the first microcirculatory network. Their distribution will therefore reflect the blood flow to and within the organ [11].

Materials and Methods

Animals. 85 sexually mature Wistar albino rats varying in weight from 250–350 g were chosen for this investigation. Surgery was conducted under ether anaesthesia.

Experimental Groups. Two groups were used as experimental controls. In two other groups the acute effects of unilateral testicular torsion on arterial blood flow were studied. The delayed effect of torsion on testicular blood flow was investigated in the last two groups.

Group 1 (Controls). In 10 animals, ^{99m}Tc (Technetium) and ^{113m}In (Indium) microspheres were injected without any further manipulation to study differences in the perfusion of both testes and to compare the results obtained with both isotopes.

Group 2 (Controls/Semicastration). In 5 animals, ^{99m}TC was injected before and ^{113m}In after right orchiectomy to imitate the situation of complete interruption of blood flow after testicular torsion. This was performed to detect any interactions between the two radioisotopes when measured.

Group 3 (Intravaginal Testicular Torsion). 20 animals underwent torsion of the right spermatic cord (Fig. 1). This group was subdivided into 4 groups of 5 animals each, in whom a clockwise torsion of either 180°, 360°, 540° or 720° was performed. ^{99m}Tc microspheres were injected before and ^{113m}In microspheres 15 seconds after torsion over a 30 second period to assess acute changes in perfusion.

Group 4 (Extravaginal Torsion: Spermatic Cord with Tunica vaginalis). After sharp dissection of the tunica vaginalis from the tunica dartos, 20 animals underwent torsion of the right spermatic cord together with the tunica vaginalis (Fig. 1). This group was also subdivided into 4 groups of 180°, 360°, 540° or 720° torsion. The

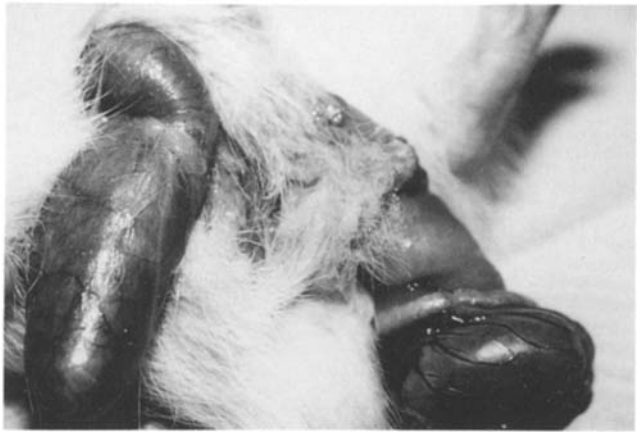

Fig. 1. On the left hand side, a torsion of the spermatic cord together with the tunica vaginalis is performed. The spermatic cord, the testis and epididymidis are covered with tunica. On the right hand side, the spermatic cord is twisted without tunica vaginalis. The testis is not covered

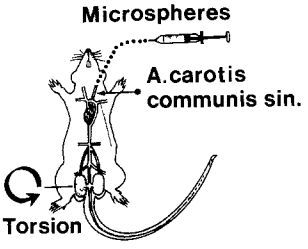

Fig. 2. The microspheres are injected into the aortic arch through a polyvinyl catheter inserted retrograde via the left common carotid artery

radiolabelled microspheres were injected in the same manner as in group 3.

Group 5 and 6. The results of the experiments performed in group 3 and 4 helped to select group 5 and 6 (5: without, and 6: with tunica vaginalis) for assessing the long term effects of testicular torsion on perfusion. 180°, 360° and 540° torsion – 5 animals each in group 5 and 6, respectively – was maintained for 1 h; then ^{99m}Tc microspheres were injected. The extent of hemorrhagic infarction was judged by the increase in testicular weight and the blue colour. Differences in the basic perfusion or weight of both sides were not taken into consideration.

Isotope Technique. Human serum albumin microspheres with a diameter between 23 and 45 microns were labelled with ^{99m}Tc or ^{113m}In respectively (CIS, 91.190 – Gif-Sur-Yvette, France). 1 ml containing 350.000 particles was injected into the aorta through a polyvinyl catheter (0.8 mm outside and 0.5 mm inside diameter) inserted retrograde from the left common carotid artery to lie in the aortic arch (Fig. 2). Similar total radiation doses were used for both ^{99m}Tc and ^{113m}In microspheres. Enough of each nuclide was injected to give a total body radioactivity of between 100.000 and 150.000 CPM (= counts per min). Both testes were then removed. The radioactivity was measured over a period of 3 min with an automatic well scintillation counter (Packard Auto-Gamma) using a pinhole collimator. The absolute value of the blood flow to the testes was not determined. The basic perfusion rate of both testes was calculated as percentage of the total body count using the ^{99m}Tc microspheres. Thereby side-differences could be considered and each animal served as its own control. The changes in blood flow were calculated by the content of the ^{113m}In microspheres injected after torsion and by comparing the differences on each side.

Results

Controls. The maximal difference between the blood flow to the right and left testis was 25%; the mean difference was about 10% with the higher values on the left side. The basic testicular perfusion rate differs by about 100% when it is determined with either ^{99m}Tc or ^{113m}In microspheres. The perfusion rate obtained with ^{99m}Tc constitutes about 0.9% of the cardiac output; the ^{113m}In value is 0.41%. We consider this difference to be due to the unphysiologically low pH (3.0–3.5) of the ^{113m}In microspheres. The pH of ^{99m}Tc is 7–9. In contrast to this, the differences in the perfusion right/left could be correctly determined with both ^{99m}Tc and ^{113m}In microspheres within a range of 5%. In the controls, the mean of the difference right/left is 17.5 ± 13.8% (^{99m}Tc; % ± SD) and 19.3 ± 18.7% (^{113m}In), respectively (Table 1). The physiological difference of the perfusion of both testes is greater than the systematic

Table 1. *Controls:* The ^{99m}Tc values of the experimental groups are presented among the controls as this isotope is injected before torsion to assess the basic perfusion. The values for the right and left testis are indicated as percentage of the total body count (= cardiac output) ± standard deviation. The mean of the difference right/left is indicated as percentage of the left testis perfusion. Statistical analysis of the differences right/left was done with a two tailed paired *t*-test

	Control animals		Experimental animals	Right orchiectomy	
	^{99m}Tc	^{113m}In	^{99m}Tc	^{99m}Tc	^{113m}In
Right testis %	0.89 ± 0.53	0.39 ± 0.26	0.84 ± 0.46	0.91 ± 0.61	0.00
Left testis %	0.91 ± 0.58	0.43 ± 0.30	0.99 ± 0.52	0.89 ± 0.43	0.53 ± 0.23
Mean of the difference right/left %	17.5 ± 13.8	19.3 ± 18.7	22.7 ± 26.5	12.8 ± 10.3	–
p-value	<0.005	<0.005	<0.001	<0.01	–

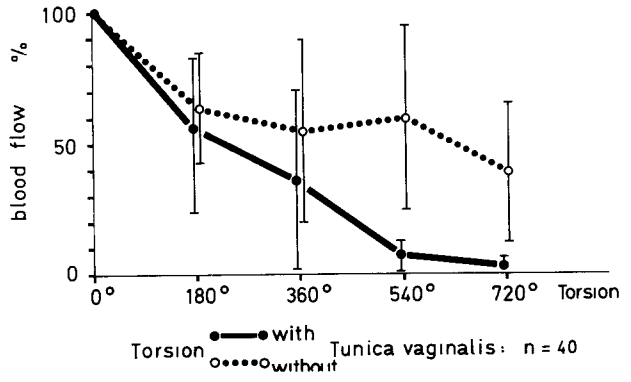

Fig. 3. Arterial blood flow immediately after testicular torsion: Torsion of the spermatic cord with tunica vaginalis results in an almost linear decrease of the arterial blood flow. After a torsion without tunica vaginalis, the decrease of the blood flow is less pronounced and not directly correlated to the degree of torsion

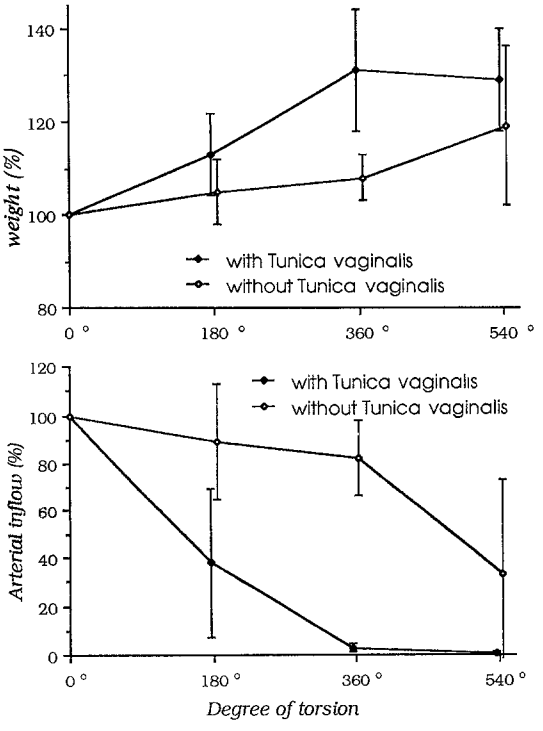

Fig. 4. Arterial blood flow and weight of twisted testicle one hour after right testicular torsion: The values are indicated as percentage of the normal contralateral side ± SD. Physiological differences of both sides are not considered. With increasing hemorrhagic infarction (= weight increase) the perfusion decreases further to zero

error of its determinitation using these radiolabelled microspheres.

Semicastration. The 5 testes removed after the injection of ^{99m}Tc showed no measurable radiactivity at the peak of ^{113m}In. The activity of ^{99m}Tc was the same whether ^{113m}In was also present or not (Table 1). The energy spectrum of the two isotopes is therefore clearly separable with the technique employed.

Torsion of the Spermatic Cord Without Tunica Vaginalis. A torsion of 180° results in a decrease of the arterial blood flow to 63.6 ± 21.3%. A torsion of 360° and 540° does not effect the perfusion rate further. After a torsion of 720° 38.8 ± 27.4% of the initial blood flow is maintained with a high standard deviation (Fig. 3). When the torsion of 180° (360°) is maintained for one hour, the perfusion rate increases again to 89 ± 22% (82 ± 16%). In contrast to that, it decreases further to 33 ± 40% after a 540° torsion (Fig. 4). In the group of 180° and 360° torsion the increase of testicular weight indicating hemorrhagic infarction is less than 10%, whereas it is 20% in the 540° group.

Torsion of the Spermatic Cord with Tunica vaginalis. Similar to the other group, a torsion of 180° results in a decrease of the perfusion to 56.4 ± 31.8%. Further torsion results in an almost linear decrease of the perfusion rate which is 2.4 ± 4.12% after a torsion of 720°. The standard deviation is also high (Fig. 3). When torsion is maintained for one hour, blood flow is reduced to 38.1 ± 31.1% with 180° torsion. A torsion of 360° decreases perfusion to 2.9 ± 1.9%, and one hour after torsion of 540° flow can hardly be measured. A maximal weight increase of 30% can be observed after torsion of 360° and 540° (Fig. 4).

Discussion

Testicular torsion is a common clinical emergency, which has found considerable experimental interest. Concern was either directed to the reactions of the ipsilateral germinative testicular epithelium and interstitial tissue in relation to the time of anoxia [8], or to the theory of contralateral testicular damage [5, 9].

Obstruction of the venous outflow causes hemorrhagic infarction as long as the arterial inflow is sufficient. This is the mechanism involved with testicular torsion, and the degree of torsion producing this situation in all experimental animals has to be determined.

Direct measurement of venous outflow by cannulation of the spermatic vein yields values too low because the acutal flow is reduced by the procedures involved in the measurement itself [2]. Instead, the amount of hemorrhagic infarction was assessed by the increase of testicular weight.

The arterial inflow was determined with radiolabelled microspheres. Albumin microspheres of 23–45 microns are trapped in the peripheral precapillary vessels during the first circulation. There are few arteriovenous shunts, which therefore can be neglected [11]. Microspheres labelled with radioactive isotopes permit reliable determination of the relative amount of injected total volume in the target organ [10].

When using two different isotopes, changes in the blood stream to the same organ can be quantified [2]. Absolute perfusion rates can be calculated when the cardiac output is known. This was not attempted as it has been recorded

previously [2, 4, 12]. The average blood flow to the testis is 20 ml/100 g/min.

Clinically both intra- and extravaginal testicular torsion can be distinguished [1]. Spontaneous testicular torsion in man results from an anatomical variation of the testicular mesentery [3]. In the rat an intravaginal torsion of the spermatic cord can be performed easily. To induce a torsion of the spermatic cord together with the tunica vaginalis (extravaginal torsion), the latter has first to be dissected free from the tunica dartos (Fig. 1).

The degree of torsion and decrease of arterial inflow correlate in a linear fashion when the spermatic cord is turned together with the tunica vaginalis. In contrast to this, a torsion of of up to 540° has no more effect than a torsion of 180° when only the spermatic cord is twisted. This probably is also important when judging the prognosis of spontaneous torsion in man. Not only the duration and degree, but also the type of torsion has an influence on the extent of damage to the organ.

Testicular torsion is a dynamic event, and inflow decreases further with time. The strangulatory effect of torsion is enhanced by tissue edema, and ultimately arterial inflow must stop when complete venous obstruction causes maximal hemorrhagic infarction. With incomplete venous obstruction a steady state results. This status was documented by measurement of arterial inflow and weight increase one hour after torsion.

Up to 540°, a torsion without tunica vaginalis does not obstruct the venous outflow completely. This finding is in accordance to the literature. In the dog, it is necessary to rotate the spermatic cord through 1,440° to produce immediate changes in the gross appearance of the testis, whereas consistent irreversible gross and microscopic changes can be obtained by twisting through 1,080° for a period of 2 h. Torsion of 360° for a period of 12 h causes no observable gross or microscopic changes in the testis [13].

The results of the presented study show clearly that the decrease of perfusion and the extent of hemorrhagic infarction do not correlate well to the degree of an intravaginal torsion. Therefore, this type of torsion is not ideal for experimental purposes. In contrast to that, the correlation is almost linear with an extravaginal torsion. Maximal hemorrhagic infarction was found with an extravaginal torsion through 360°–540°. Further torsion may result in ischemia. As experimental model in rat, we therefore recommend a torsion with tunica vaginalis through 540°.

References

1. Bartsch G, Schachtner W, Mikuz G, Janetschek G (in press) Operative urology. Testicular torsion. BC Decker Toronto Philadelphia
2. Damber JE, Janson PO (1977) Methodological aspects of testicular blood flow measurements in rats. Acta Physiol Scand 101:278–285
3. Gier HT, Marion GB (1970) The testis. Development of the mammalian testis. Academic Press, New York London, pp 2–45
4. Glover TD (1965) Changes in blood flow in the testis and epididymis of the rat following artificial cryptorchidism. Acta endocrinol (Kbh) Suppl 100:38
5. Hadziselimovic F, Snyder H, Duckett J, Howards S (1986) Testicular histology in children with unilateral testicular torsion. J Urol 136:208–210
6. Hundeicker M (1970) Beobachtungen am Gefäßsystem des Rattenhodens nach Venen- und Arterienunterbindung. Andrologie 2:125–131
7. Kaya M, Harrison RG (1975) An analysis of the effect of ischemia on testicular ultrastructure. J Pathol 117:105–117
8. Ludwig G, Haselberger J, Münzenmaier R (1979) Frühveränderungen des Hodengewebes bei experimenteller Samenstrangtorsion. Urologe A18:294–299
9. Nagler HM, De Vere White R (1982) The effect of testicular torsion on the contralateral testis. J Urol 128:1343–1348
10. Neutze JM, Wyler F, Rudolph AM (1968) Use of radioactive microspheres to assess distribution of cardiac output in rabbits. Am J Physiol 215:486–495
11. Rudolph AM, Heymann MA (1967) The circulation of the fetus in utero: methods for studying distribution of blood flow, cardiac output and organ blood flow. Circ Res 21:163–184
12. Setchell BP (1970) The testis. Testicular blood supply, lymphatic drainage, and secretion of fluid. Academic Press, New York London, pp 101–239
13. Sonda LP, Lapides J (1961) Experimental torsion of the spermatic cord. Surg Forum 12:502–510

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