Original Article

Is Testicular Tissue Resection Effective in Testicular Compartment Syndrome?

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Abstract

Background: There have been many testicular losses due to testicular compartment syndrome (TCS). Studies are ongoing to lower the pressure within tunica vaginalis during TCS. **Aims:** To provide enough space for reperfusion of the testicular tissue and to reduce intratesticular pressure by resecting testicular tissue in the affected testis for treatment of TCS. **Materials and Methods:** The study was designed as a prospective randomized animal study. A total of 24 Wistar albino adult rats were randomly divided into three groups. After torsion surgery group 1 underwent detorsion + testicular tissue resection (TTR), while only detorsion was performed in group 2. The control group did not undergo any procedures. At the postoperative 5th day all subjects were sacrificed, and their testes were evaluated in terms of histologic findings, apoptosis, and microangiogenesis. One-way ANOVA and Tukey's test were used for analysis. **Results:** According to *Johnsen scores*, all the groups were statistically different from each other and the damage in group 1 was less than in group 2 ($P < 0.05$). *Factor VIII expressions* in surgical groups were significantly higher than in the control group ($P < 0.05$). However, the surgical groups did not show any significant difference between each other ($P > 0.05$). *Apoptotic cell counts* were higher in both surgical groups than in the control group. Also, there was significantly higher apoptotic cell count in group 2 than in group 1 ($P < 0.05$). **Conclusions:** The injury secondary to TCS is lower when TTR is performed. In the cases in which tunica vaginalis graft could not be obtained or in the delayed cases, TTR may be useful.

Keywords: *Detorsion, rat study, testicular compartment syndrome, testis torsion, tissue resection*

Introduction

Testicular compartment syndrome (TCS) can occur due to inflammatory diseases such as testis torsion or epididymo-orchitis. In TCS, inflammation and edema may cause severe compression of testicular parenchyma and vascular tissues within tunica albuginea and without sufficient and rapid intervention those tissues could be damaged irreversibly within hours. Although up to 40% of testicular tissue can be damaged due to testis torsion, studies focused on involved mechanisms and treatment guidelines are limited.[1]

The main factor contributing to testicular loss might be the occult course of TCS in the early hours. The patient might be admitted to the hospital in time, but the increased intratesticular pressure may not be high enough to slow down the flow on the surface of the affected testis at the time of ultrasonography (US). Moreover, the color improvement of the detorsioned testis during the surgery might keep surgeons from foreseeing the edema or damage related to ischemia–reperfusion injury (IRI).

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The studies focused on finding a viable treatment option for TCS, which is as a potential threat during the diseases like testis torsion, are ongoing. In this animal study, we wanted to evaluate a new approach for treating TCS. We aimed to create enough space for the reperfusion of the testicular tissue and to reduce intratesticular pressure by excising a portion of testicular tissue in the affected testis. We also aimed to compare the results of this technique with the histopathological results of the testicles that had been successfully detorsioned.

Materials and Methods

Local ethics committee approved our study (2019 HADYEK-32). Twenty-four Wistar albino adult rats weighing 250–300 g were included in the study and randomly divided into three groups. The rats were kept in cages in the laboratory for an adaptation period of one week with readily available rat chow and freshwater. The cages were in a room with temperature levels of 20–23°C (68–73°F). The sleep/awareness periods were adjusted as 12 hours each according to the rats' life cycle.

Surgical stage, grouping, and tissue preparation

Four experienced certified researchers conducted all the animal experiments. In the first stage, anesthesia was performed by injecting 20 mg/kg ketamine + 1.5 mL xylazine intraperitoneally to each subject. After that, all rats except control group were numerated and scrotal exploration was performed in the numerical order, in accordance with the ethics and sterility rules. Left testes of 16 subjects were rotated 1800° in the counterclockwise direction. Each testis was fixed to the scrotum base to keep the testes from spontaneous detorsion. Scrotum was closed again, and an incubation period of 120 minutes was started. During this time, almost all the subjects recovered from anesthesia. Only one rat died at this stage and was excluded from the study. After the incubation period was completed, the subjects were anesthetized in the same numerical order to equalize the torsion time of all the testes. Scrotal explorations were repeated, torsioned testes were detorsioned, and hot sterile compress was applied for 15 minutes. Testis color turned to pink in 8 of the rats. However, in the other 7, the color remained dark rose (group 1). Reperfused subjects were allocated as group 2, and their scrotal incisions were closed.

A 2 cm-long incision was performed to the tunica albuginea of each rat in group 1. A bright red color was seen on the bulging tubules through incision. When we tried to close the incision, the color of the testis turned to dark rose again, and based upon these observations, it was thought that this grouped developed TCS. The bulging tubules were elevated slightly and ligated by using 4/0 polyglactin suture and were resected. Based on the weight loss of each testis, the resected tissues were approximately 1/6 of the testes. The incision was closed with 3/0 polyglactin suture. After a 10-minute incubation, the testis was still pink and the scrotal incision was closed. This procedure was repeated for each rat in group 1. All surgery and anesthesia times were recorded separately. By the way, we had three groups. The first group was control group which was consisted of eight healthy rats. They were not operated and anesthetized. At the end, they sacrificed, and their testes were examined. The next group was group 1, and it was composed of the seven rats which were evaluated as they encountered compartment syndrome. The last eight was recorded as group 2. They had recovered after detorsion, and therefore, they were evaluated as they did not encounter compartment syndrome during the experiment.

On postoperative 5th day, the rats were anesthetized again. All rats including control group were sacrificed by decapitation. Left testes of all subjects were resected and put into separate boxes filled with formaldehyde. The specimens were delivered to histologic research laboratory.

Histologic procedure

The testes were fixed with 10% formaldehyde solution. After immersion and clearing processes, the tissues were embedded into paraffin wax. Five to six μm sections were cut from paraffin blocks. These sections were stained with hematoxylin-eosin and mounted with Entellan® (Entellan new, Merck®). When the slides were ready, they were inspected under Olympus BX53 microscope. Histopathological findings were evaluated according to Johnsen testicular biopsy score (JTBS).[2]

Immunohistochemical analyses

Factor VIII immunoreactivity in rats from groups 1 and 2 was measured by using avidin-biotin-peroxidase complex. In this method, after deparaffinization and retrieving epitopes, the slides were incubated in 3% hydrogen peroxide. After incubating with antibodies, Gill's hematoxylin method was used for counterstaining. After immersion, the slides were inspected with Olympus BX53 microscope. Ten different areas were inspected for each slide. The immunoreactivity levels were evaluated with ImageJ software.

TUNEL method

Apoptotic cells were determined in the sections using *In Situ* Cell Detection Apoptosis Fluorescein Kit (Roche®). Staining, deparaffinization, rehydration, and rinsing in PBS procedures were followed according to manufacturer's instructions. Then, the slides were

placed into sodium citrate buffer and transferred into a microwave (350W for 5 minutes). After cooling, they were rinsed in PBS and incubated with TUNEL reaction mixture at 37°C for 60 minutes. After rinsing in PBS and counterstaining, the slides were mounted with glycerol solution and inspected under Olympus BX53 microscope. Apoptotic cells in 50 different areas were counted for apoptotic index.

Statistical analyses

IBM SPSS Statistics for Windows, v25.0 (IBM Corp. Released 2017. Armonk, NY) was used for statistical analyses. The results were given in mean ± standard deviation (SD). One-way ANOVA test was used for comparison between three groups. Tukey's test was used as post-hoc test. Statistical value of $P < 0.05$ was considered as significant.

Results

Times for surgery and anesthesia are given in Table 1. There was no significant difference in surgery and anesthesia times between groups 1 and 2 during the torsion surgery ($P > 0.05$). However, torsion time in group 1 was significantly higher ($P = 0.03$). Anesthesia time did not show any significant difference between the two groups during detorsion and/or testicular tissue resection (TTR) ($P > 0.05$), but the surgery time of TTR was significantly higher in group 1 ($P < 0.05$).

Results of histologic evaluation

According to JTBS, while the control group was normal, there was a significant tubular damage in both groups 1 and 2 [Figure 1] ($P = 0.0001$). The statistical expressions of these changes were given in Table 2. All the groups were statistically different from each other, and the damage in group 1 was less than in group 2 ($P < 0.05$).

Table 1: Anesthesia and surgery times of groups

Time (min)	Group 1 (*n*=7)	Group 2 (*n*=8)	*P*
Anesthesia (1)	99.57±8.42	96.37±8.73	0.48
Surgery (1)	9.85±1.57	10.75±1.48	0.29
Torsion time	133.00±3.46	128.62±3.46	0.03*
Anesthesia (2)	120.57±7.13	112.25±8.58	0.06
Surgery (2)	44.71±2.98	29.37±3.50	0.00*

The data were given in mean±SD in the table. Anesthesia, (1) the anesthesia time during the torsion surgery; surgery, (1) the surgery time during the torsion surgery; anesthesia, (2) the anesthesia time during the detorsion and/or lobectomy; surgery, (2) the surgery time during the detorsion and/or lobectomy. *P<0.05

Table 2: Johnsen testicular biopsy score results

Groups	Control	G1	G2	*P*
JTBS	9.87±0.33[a]	4.68±1.40[b]	2.96±1.12[c]	0.0001

The data are given as mean±standard deviation. There is no statistically significant difference between the groups which are demonstrated with the same letter (a, b, or c). P<0.05

Table 3: TUNEL results

Groups	Control	G1	G2	*P*
TUNEL Positive Cell	0.43±0.83[a]	5.41±3.66[b]	7.19±4.43[c]	0.0001

The data are given as mean±standard deviation. There is no statistically significant difference between the groups which are demonstrated with the same letter (a, b, or c). P<0.05

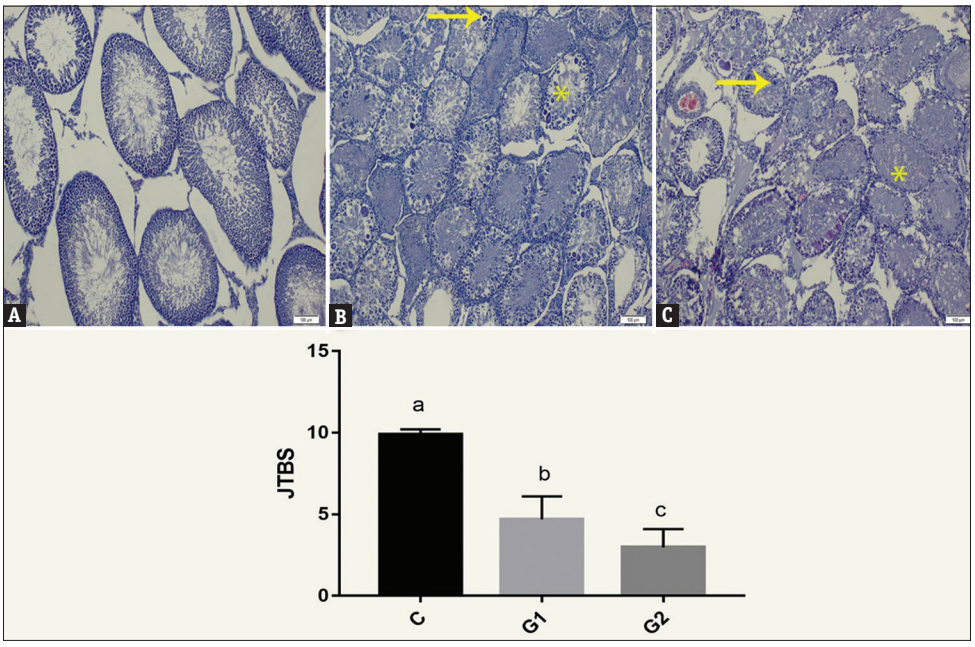

Figure 1: (A) Control group (B) G1: Group 1 (C) G2: Group 2. Yellow arrow indicates the deterioration in giant cells, and asterisk indicates the deterioration in spermatogenic series. (X100)

Results of immunohistochemical evaluation

Factor VIII expressions in surgical groups were significantly higher than in the control group ($P < 0.05$) [Figure 2]. However, there was no significant difference between surgical groups ($P > 0.05$).

TUNEL reaction results

Apoptotic cell counts were significantly different between the groups ($P = 0.0001$) [Figure 3, Table 3]. It was higher in both surgical groups than in the control group. Moreover, apoptotic cell count was significantly higher in group 2 than in group 1 ($P < 0.05$).

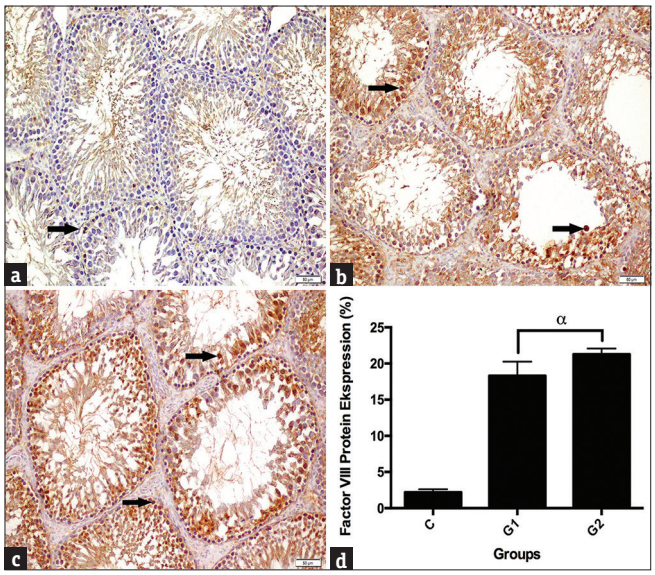

Figure 2: Factor VIII immune staining in the subjects of control group (a) group 1 (b) and group 2 (c) (Dark arrow indicates the immune reactive areas) (d) Histopathological scores are given as mean ± standard deviation (SD) in histogram. One-way ANOVA and Tukey post-hoc test were used. (α $P < 0.05$ control group; β $P < 0.05$ Group 1; γ $P < 0.05$ Group 2)

Discussion

TCS is a urological emergency in which increased pressure in a limited area compresses microcirculation and results in hypoxia-induced tissue infarction, as in other compartment syndromes. TCS usually occurs after testis torsion. On the other hand, the readers should keep in mind that TCS is not only a result of testis torsion. However, other inflammatory factors that affect the testicle may result in TCS as well. In this study, we did not dedicatedly focus on testis torsion, but rather on the effects of TCS.[1,3]

In testis torsion, macrocirculation can deteriorate within hours after microcirculation stops, even if the revascularization is re-established. After detorsion, examining only testis's color recovery which indicates macrocirculation of superficial vessels may mislead the clinician in terms of testis revascularization. However, even after a successful detorsion, TCS may manifest within hours secondary to the deterioration of microcirculation and IRI. It may be the reason for >25% of the successful detorsion cases ending up with testicular atrophy.[4]

Testis torsion requires an immediate intervention. However, there has not been a consensus on how and when the intervention should be done. There is a common notion among urologists that in testis torsion if the ischemia duration exceeds 4–6 hours, the probability of recovering the testicle will be low. In

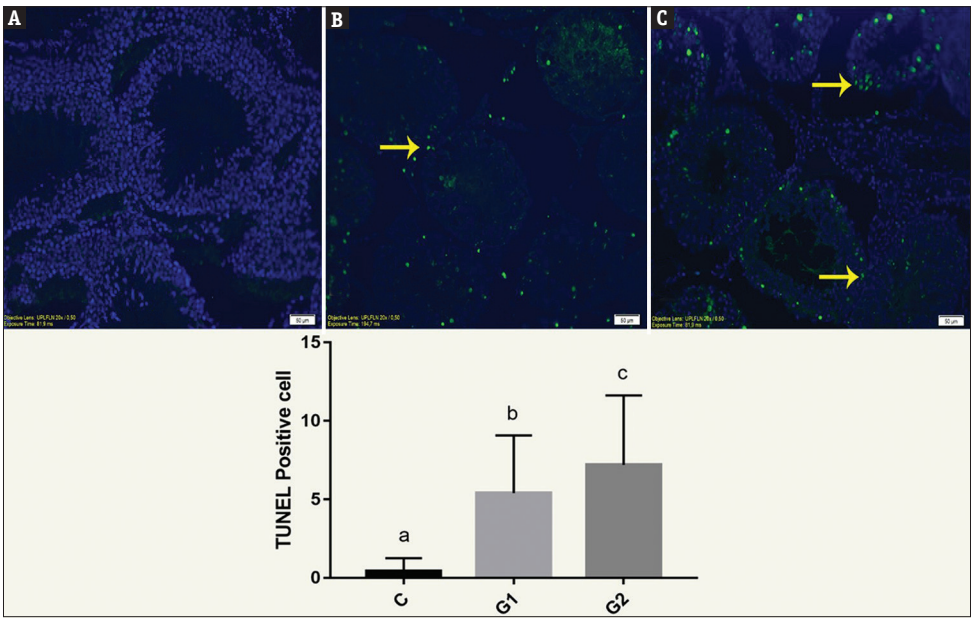

Figure 3: (A) Control group (B) G1: Group 1 (C) G2: Group 2. Yellow arrow indicates the apoptotic cells. (X200)

some studies, the testicle salvage rate was >90% if the treatments were done in the first 6 hours, and in many studies, the ischemia times ≤24 hours were reported as salvageable for testis.[5-9] Another controversial issue is the degree of twisting. Although Howe *et al*. reported that the twisting degree gave information about the prognosis after detorsion, Cimador *et al*. claimed that it could not be a prognostic factor in predicting the consequences.[10,11] Another issue is the type of intervention. The success rates with manual detorsion varied from 68 to 86%; however, the limitations of manual detorsion are difficulties in detecting the direction and the degree of twisting precisely.[12] Traditional practice in surgery is observing the color recovery of testis after detorsion. If the color does not improve, orchiectomy will be performed due to the risk of contralateral testis injury via immune mechanisms.[13] Despite this general approach, a debate about whether orchiectomy is necessary for the patients whose torsion time was >24 hours is still ongoing.[14]

TCS should be suspected when color improvement cannot be achieved after surgical detorsion performed to a patient with testis torsion and heat application to his testicle with a sterile compress.[1,13] In this case, a longitudinal incision on the lateral side of the testis provides a visible reperfusion. However, in a testicle in which microcirculation stopped and macrocirculation has nearly stopped, the pressure within tunica albuginea decreases very quickly. Kutikov *et al*. were able to measure this phenomenon by using a handheld compartment monitor device in their third case.[1] They reported that in the normal testis, the intratesticular pressure was 5 mmHg while it was 34 mmHg in the testicle with TCS. After they incised the testis, the pressure decreased to 5 mmHg. Furthermore, intratesticular pressure increased to 46 mmHg when the incision closed. This could be explained with hyperflow which results in congestion in the testis whose intratesticular pressure decreased very quickly. Thus, when a few milliliters of blood rushed into the testicle in which the edema already developed, the testicle will no longer fit into tunica albuginea. As Kutikov *et al*. mentioned, the problem will worsen if the testis with TCS is closed after incision. In addition, if the incision is performed, it is mandatory to widen the compartment's volume by a surgical technique. Kutikov *et al*. gained a considerable success by using tunica vaginalis graft which was suggested by Ferguson *et al*.[1,15] The necessity of performing a compartment widening was the main cause, which led us not to investigate the effects of incision with an incision study group. The rats in an only incision group would have worse parenchyma than the others after closure.

Using a graft or incising testis can provide an increase in the space within the testis; hence, a decrease in the intratesticular pressure will be ensured. Figueroa, Sharifi, and Quintaes also reported the benefits of these techniques.[16-18] However, not all the researchers reported success with these methods. Kolbe, Jozsa, and Oktar did not find the benefits in question in animal studies.[19-21] The reason why these benefits could not have been shown in animal studies might be related to the difficulties in studying animals and the fact that there has not been a consensus on the adequate volume by which to increase the space within the affected testis. Kutikov *et al*. successfully used a tunica vaginalis graft with the diameters of 2 × 3 cm, in a 16-year-old patient.[1] In our study, we used TTR instead of graft in rats with TCS. By this means, we aimed to increase the space within tunica albuginea by reducing the amount of intratesticular tissue. We resected approximately 1/6 of the whole tubules and got significant success in terms of histological evaluation. As we know, a human testis contains 250–290 lobules.[22] However, a lobule structure in rats has not been described yet.[23] Therefore, tissue damage in rats might be more diffused than in human. So, we are aware of the limitation of adapting this technique in humans. However, this study is focused on the feasibility and effectiveness of this technique in general.

The main idea that evoked the thought that TTR could be useful was the fact that testicular damage occurred heterogeneously after TCS. Every part of the testicular tissue does not get affected from TCS equally, and in many cases, the damage is heterogeneous.[1,20] Thus, we thought that resecting the affected tubules would not make any more harm and could be useful in reducing the intratesticular pressure. However, in this study, such a selective resection was not performed. The resections made directly because we aimed to determine whether such a compartment widening will work or not. A selective dissection under a microscope may be the main focus of another study.

There is no consensus on the TCS model in rats. Many researchers used 720° torsion to improve a testis torsion model. However, it is not really known whether TCS was adequately established after this degree of torsion. Kolbe *et al*. reported that they achieved the TCS model after 720° torsion lasting up to 12 hours.[19] We performed 1800° torsion lasting for 120 minutes and showed that a TCS model can be obtained in a shorter span of time. When we look at the results, the torsion time in group 1 was approximately 5 minutes longer than in group 2. The researchers hurried up with both groups to equalize the time between the first and the second surgery.

However, group 1 was taken to the operation second. Therefore, the torsion time was statistically significantly longer in group 1 ($P = 0.03$). Thus, it can be thought that 120 minutes may be the critical time for 1800° torsion. When this time is exceeded TCS model can be provided.

In this study, we evaluated spermatogenic maturation by JTBS.[2,19] Accordingly, testicular injury was significantly higher both in groups 1 and 2 than in the control group. In addition, the injury was significantly lower in rats that underwent TTR. Also, the apoptotic cell count, which was determined by TUNEL method, was higher in group 2 than in group 1. These findings suggest that the rats who underwent TTR had better testicular parenchyma than group 2 at the postoperative fifth day.

Another area that we investigated was the microcirculation in the tissue. We used factor VIII levels to evaluate the microcapillary angiogenesis.[24,25] Although there was not a significant difference between groups 1 and 2 regarding factor VIII levels, the angiogenesis levels in these groups were significantly higher than in the control group at the end of the postoperative fifth day. This finding may suggest that revascularization was provided successfully via both detorsion and TTR. However, more comprehensive studies are needed to evaluate the long-term results of this increased angiogenesis.

No matter which surgical technique is chosen, a minor damage will occur in the testicle after TCS treatment. We saw this damage in two cases of Kutikov's report and in almost all the rats in our study. The effect of this injury on fertility and hormone levels, the advantages of adding antioxidants to the treatment, pros and cons of using graft and TTR or combination treatment are not yet known. Also, we do not have any idea whether TTR will trigger an autoimmune reaction which will give harm to the other testicle.

In this study, the fact that we diagnosed vascularization status by conventional inspection during detorsion may be considered as a limitation. The lack of weight and volume data of the testicles can be another limitation. However, it is obvious that the pressure monitorization would have been much more useful and logical instead of these data.

This study aimed to describe a new surgical procedure in TCS cases. However, this is a preliminary study of a novel technique which might be a candidate to be a last resort measure. We did not compare this technique with tunica albuginea incision or flap/graft usage or another surgical technique. These may be the subject of other future studies. Therefore, we do not claim that TTR is superior to other surgical procedures. In this study, TTR was compared with detorsion and it is only aimed to show that TTR gives favorable results than detorsion alone. We believe that TTR might lower the rates of orchiectomy even in the testicles within worst pathological stress.

Fascial graft usage can be recommended in case of TCS. However, it should not be overlooked that whatever we do, some areas in the testicular tissue will not be saved, especially in delayed cases. Orchiectomy rates might be reduced in delayed cases if the tubules which seem worse than the others after tunica albuginea incision, are resected. In addition, tunica vaginalis may be fragile and fascial plans may not be distinguished in the complex cases such as epididymo-orchitis, Fournier gangrene, >24 hours delayed cases, or severe traumas. In these cases, giving the testicles a chance to survive by performing TTR instead of orchiectomy may be a sensible and practical option.

Conclusion

We believe that adequate volume increase should be achieved after TCS to demonstrate the histopathological benefits of both the graft usage and TTR. In this study, the required volume increase was determined as 1/6 of rat's testicular volume. In cases in which tunica vaginalis graft could not be obtained or in the delayed cases, TTR after detorsion might be a ray of hope for saving the testis. However, more studies are needed to clarify the uncertainties and to define more specific treatment options.

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Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Kutikov A, Casale P, White MA, Meyer WA, Chang A, Gosalbez R, *et al*. Testicular compartment syndrome: A new approach to conceptualizing and managing testicular torsion. Urology 2008;72:786-9.
2. Johnsen SG. Testicular biopsy score count--A method for registration of spermatogenesis in human testes: Normal values and results in 335 hypogonadal males. Hormones 1970;1:2-25.
3. Gandhi J, Dagur G, Sheynkin YR, Smith NL, Khan SA. Testicular compartment syndrome: An overview of pathophysiology, etiology, evaluation, and management. Transl Androl Urol 2016;5:927-34.
4. Sessions AE, Rabinowitz R, Hulbert WC, Goldstein MM, Mevorach RA. Testicular torsion: Direction, degree, duration and disinformation. J Urol 2003;169:663-5.

5. Rouzrokh M, Mirshemirani A, Khaleghnejad-Tabari A. Outcomes of second look exploration in testicular torsion of children. Iran J Pediatr 2015;25:e528.
6. Visser AJ, Heyns CF. Testicular function after torsion of the spermatic cord. BJU Int 2003;92:200-3.
7. Anderson MJ, Dunn JK, Lipshultz LI, Coburn M. Semen quality and endocrine parameters after acute testicular torsion. J Urol 1992;147:1545-50.
8. Moghimian M, Soltani M, Abtahi H, Adabi J, Jajarmy N. Protective effect of tunica albuginea incision with tunica vaginalis flap coverage on tissue damage and oxidative stress following testicular torsion: Role of duration of ischemia. J Pediatr Urol 2016;12:390. e1-390.e6.
9. Chu DI, Gupta K, Kawal T, Van Batavia JP, Bowen DK, Zaontz MR, *et al*. Tunica vaginalis flap for salvaging testicular torsion: A matched cohort analysis. J Pediatr Urol 2018;14:329. e1-329.e7.
10. Howe AS, Vasudevan V, Kongnyuy M, Rychik K, Thomas LA, Matuskova M, *et al*. Degree of twisting and duration of symptoms are prognostic factors of testis salvage during episodes of testicular torsion. Transl Androl Urol 2017;6:1159-66.
11. Cimador M, DiPace MR, Castagnetti M, DeGrazia E. Predictors of testicular viability in testicular torsion. J Pediatr Urol 2007;3:387-90.
12. Yin S, Trainor JL. Diagnosis and management of testicular torsion, torsion of the appendix testis, and epididymitis. Clin Pediatr Emerg Med 2009;10:38-44.
13. Blake W, Moore P, Harry P. Testicular Torsion. In: Graham S, Keane T, Glenn J, editors. Glenn Urologic Surgery. 11th ed. Ankara: Güneş Tıp Kitabevi; 2011:450-1.
14. Radmayr C, Bogaert G, Dogan H, Kocvara R, Nijman J, Stein R, *et al*. EAU Guidelines on Paediatric Urology. In: EAU Guidelines. Arnhem, The Netherlands: EAU Guidelines Office; 2018:21-2.
15. Ferguson GG, Brandes SB. Gunshot wound injury of the testis: The use of tunica vaginalis and polytetrafluoroethylene grafts for reconstruction. J Urol 2007;178:2462-5.
16. Figueroa V, Pippi Salle JL, Braga LH, Romao R, Koyle MA, Bägli DJ, *et al*. Comparative analysis of detorsion alone versus detorsion and tunica albuginea decompression (fasciotomy) with tunica vaginalis flap coverage in the surgical management of prolonged testicular ischemia. J Urol 2012;188 (4 Suppl):1417-22.
17. Sharifi LK, Patten DK, Thomas R, Alchikhali T, Vig S. Compartment syndrome of the testicle: A case report and review of the literature. J Clin Urol 2014;7:299-302.
18. Quintaes IP, Tatsuo ES, Paulo DN, Musso C, Boasquevisque PC. Decompressive fasciotomy in testicular torsion of the spermatic cord in rats. Acta Cir Bras 2013;28:423-9.
19. Kolbe A, Sun CC, Hill JL. Unpredictability of capsulotomy in testicular torsion. J Pediatr Surg 1987;22:1105-9.
20. Józsa T, Klárik Z, Kiss F, Tóth E, Mester A, Hargitai Z, *et al*. Morphological and microcirculatory evaluation of the rat testis after detorsion with or without a capsular release with a tunica vaginalis flap. Asian J Androl 2016;18:462-6.
21. Oktar T, Kucukdurmaz F, Erdem S, Kilicaslan I, Ceylan C, Sanli O, *et al*. Tunica albuginea decompression fails to alter the injury of prolonged arterial occlusion during testicular torsion. J Urol 2013;190:239-43.
22. Countouris N, Holstein AF. [How many testicular lobules does a human testicle contain? Reexamination of an old problem]. Andrologia 1985;17:525-31.
23. Creasy D, Bube A, de Rijk E, Kandori H, Kuwahara M, Masson R, *et al*. Proliferative and nonproliferative lesions of the rat and mouse male reproductive system. Toxicol Pathol 2012;40 (6 Suppl):40S-121.
24. Weidner N, Semple JP, Welch WR, Folkman J. Tumor angiogenesis and metastasis--correlation in invasive breast carcinoma. N Engl J Med 1991;324:1-8.
25. Tang XY, Hong HS, Chen LL, Lin XH, Lin JH, Lin Z. Effects of exercise of different intensities on the angiogenesis, infarct healing, and function of the left ventricle in postmyocardial infarction rats. Coron Artery Dis 2011;22:497-506.