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The process of spermatogenesis liberates significant heat and the scrotum has a role in body thermoregulation

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Summary The temperature in human testis is 2–3 °C less than that of body providing a suitable environment for sperm production. Pampiniform plexus play a major role in this. Authors question the full function of Pampiniform plexus; if it is sufficiently efficient to maintain the optimal temperature, why testes are not retained in abdomen. The present hypothesis states that during the process of spermatogenesis a large amount of heat is liberated as a bye product of energy utilization. Testes are purposefully kept away in the dangling scrotum to exclude the damage otherwise it would have caused to visceral organs from the heat it produced. The heat from testes is carefully liberated by scrotum. The thin skin with no subcutaneous fat, scanty hair distribution and presence of more sweat glands on it permits easy escape of heat. On exposure to cold, the scrotal surface area is minimized by rugosities for heat conservation and cremaster muscles lift testes closer to abdomen to provide heat to body.
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Introduction

The human body temperature is regulated by a number of mechanisms maintaining balance between heat production and its loss. The visceral organs, liver and intestines play a major role in heat generation. This leads to increase in intraabdominal temperature. Testes are protected from this hyperthermic environment for continuous sperm production, as follows. During the second half of seventh month of fetal life, testes developed on the dorsum of the abdominal wall descend through inguinal canal to house in scrotum. Suspension of testes outside abdomen is a characteristic feature of homeothermic animals, though exceptions are present. The testes in scrotum facilitates the production of viable and mature spermatozoa in a comparatively cool environment [1–5] where temperature is usually 3 °C below body temperature [6]. Mieusset et al. [7] reported that an increase

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in 1.5–2 °C of scrotal temperature inhibited spermatogenesis. This was supported by our earlier report. Wearing tight undergarments, scrotum pooled in hot water while bathing and certain occupations where constant sitting was essential, caused temporary infertility due to increased scrotal temperature [8].

The fertility potentiality of a male depends on the number and quality of motility of his spermatozoa [9]. Spermatogenesis, which takes place in seminiferous tubules during active sexual life, is controlled mainly by hormones from anterior pituitary and testes. Spermatogenesis includes both mitotic and meiotic division ending to release millions of spermatozoa per day.

Hypothesis

The present hypothesis states that testes generate large amount of heat, as a bye product of energy used in the process of spermatogenesis. Protection from this heat is assured to testes as well as other organs in abdomen, by keeping testes away in scrotum. Temperature of testis is unknown [6]. It keeps testes away from body when surrounding temperature is high. During exposure to cold, cremaster and dartos muscles lift testes up nearer to abdomen to maintain body temperature by giving heat. Skin of scrotum is well organized for the liberation of heat like wise.

Supporting the hypothesis the following points are placed.

1. The chemical work enables cells and organisms to grow, maintain a suitable environment and store information needed for reproduction and normal activities [14]. Jacobs [16], Norbury and Nurse [17] and Taiz and Zeiger [18] while reviewing the cell cycle in animals and plants pointed out the utilization of energy at several levels. Approximately 40% of utilized chemical energy in a cell is converted into the form of heat energy [19,20].Follicle stimulating hormone (FSH) and testosterone, are major hormonal factors responsible for the production of spermatozoa. Hormone receptor complex takes part at different destined levels during sperm production. FSH initiates spermatogenesis. Stimulus on germinal cells leads to a number of activities like movement of ions across cell membrane, spreading of impulse followed by several physical, mechanical and chemical changes [15], leading to the formation of millions of spermatozoa in a day. Different authors reported this value as 120 million [10], 300 million [11], and 500 million [12]. Approximately 50% of produced spermatozoa perish in the epididymis [13]. This shows the sperm production as 240–1000 million per day.The above factors when considered, from the formation of FSH receptor complex till spermiogenesis where spermatozoa are released to tubular lumen, a large amount of chemical energy must have been used ending in liberation of profuse amount of heat. This must have been sufficient to damage testicles themselves and other organs, had they remained in abdomen. By shifting testes from abdomen to scrotum other organs in abdomen are protected. Imagine, if intestine where epithelium is renewed every 2–5 days [21], generating heat was to be shifted instead of testes?
2. Waites and Moule [22] measured the temperature of different blood vessels and tissues in ram testes. They observed a decrease in temperature from 39 to 34 °C as blood reached from internal spermatic to testicular artery. On the other hand an increase was noted from 33 to 38.6 °C as blood moved from testicular to internal spermatic vein. This has been explained in terms of counter current heat exchange mechanism in pampiniform plexus [23]. Such an elaborate study was not reported in man. A conclusion in man could not be drawn as it happens in ram or other animals. Such a proposal was accepted by medical fraternity in case of epididymis [24].
3. Function of pampiniform plexus is questionable. Had it been such an excellent mechanism to provide a cooler environment for testes, testes could have been very well detained inside abdomen. If pampiniform plexus is efficient enough to maintain the optimum temperature, why testes are lifted nearer to abdomen when exposed to cold? Or kept away in warm surrounding? Interestingly this system does not exist in some mammals including elephant [12].
4. In man, dangling scrotum helps in body thermoregulation. The large amount of heat produced during spermatogenesis is liberated through scrotum. A number of supporting mechanisms like thin skin with high vascularisation, scanty hair, abundant sweat glands, and absence of subcutaneous fat in scrotum facilitate easy liberation of heat. Whenever heat is more in testes or exposed to warm ambient temperature, the scrotal skin becomes lose, increasing its surface area and scrotal muscles relax to bring testes away from body to exclude damage.On the other hand exposure to cold permits the scrotum to form rugose reducing the surface area and a

minimal release of heat. The heat generated by testes may be easily conveyed to the body by the proximity the sac has due to contraction of dartos and cremaster muscle. The efficient mechanism of heat liberation and conservation of scrotal skin question the authority of pampiniform plexus.

5. In cold-blooded animals, pisces, amphibia and reptiles, intraabdominal testes help them to keep body warm. Among mammals, in rodents, bats and insectivorous the testes are scrotal during breeding and inguinal or abdominal at other times [6,12,25]. This adaptation during breeding time may be because heat generation from sperm production is more and this could be liberated properly without injuring any visceral organ.
6. In hibernating mammals testes remain intraabdominal during the process of hibernation and intrascrotal otherwise [12]. This may be considered as supportive mechanism to provide heat for body, though sperm production is likely to be minimal during hibernation. Even bit of heat available is conserved.
7. Testes are intraabdominal in mammals like elephant, whale, and dolphin and inguinal in seal [6]. In elephant the large intraabdominal volume and surface area may help in dissipating the heat generated by testes. Similar may be the mechanism in whale, dolphin and seal along with animal's constant contact with water to liberate heat profusely.
8. Van Denmark and Free [40] reported decreased sperm output in ram, bull and boar in warm months and also after transferring animals to continents with excessively hot climates. This explains for reducing of total heat in the body protection. Likewise the increased sperm production in cold season is a measure to provide heat to the body. Scanty report, on increased human spermatogenesis during winter may be noted [20].
9. It has been proved that loss of temperature differential is associated with idiopathic infertility [26]. The absence of spermatogenesis in cryptorchidism is attributed to high intraabdominal temperature [27]. Varicocele, a tortuous dilation of testicular veins resulting in stagnation of venous blood in the pampiniform plexus is one of the causes of male infertility [28,29]. Several hypotheses have been put forward to explain the adverse influence of varicocele on spermatogenesis. The major ones include hyperthermia theory [30,31], altered testicular steroidogenesis [32] and mechanical compression [30,31]. But none of these have been proved beyond reasonable doubt [30]. The experimental and clinical evidence showed the pathological changes that occur in the affected testes are seen in the contralateral testes [33–35]. Nagler and Zippe [36] explained that the internal communication of the left right pampiniform plexus contribute to this phenomenon.However varicocele remains a controversial subject. All infertility cases are not due to varicocele and all varicocele patients do not show infertility. Moreover there is no direct correlation between degree of subfertility and grade of varicocele. The pathological degenerative changes of the uninvolved testes are in need of better explanations [37,38]. We propose that it is the increased heat due to defective counter current and heat generated by the testes that causes degenerative changes in ipsilateral as well as contralateral testis leading to subfertility. Zorgniotti and colleagues [42] measured the temperature of scrotal skin overlying the most prominent anterior portion of the testis of varicocele patients and compared to that of tympanic membrane. Results were compared to that of normal subjects. They observed difference in both temperatures. The significant increase in the temperature of tympanic membrane of patients seen may be due to increased core body temperature contributed by testes where the cooling mechanism turned defective.In summary all arguments above are in support of the hypothesis.

Evaluation of hypothesis

We propose to measure scrotal skin temperature by employing infrared thermometry as suggested by Zorgniotti and Mac Leod [35] and Zorgniotti et al. [42] or by thermocouple. The tests are to be conducted in air-conditioned room with out usage of fan. Subjects or patients are kept in supine position. Bare below waist in standing position the temperature lowers down by 0.6 °C [35].

Waist, groin, scrotum and armpit on both sides are cleaned with distilled water having room temperature and dried. After 5 min, the temperature is measured in groin of both sides by holding the skin into folds at different levels. The chosen places on scrotum are upper and lower poles and mid level of both testes as well as anterior and posterior median raphe (of scrotum). The values from scrotum are compared to that of at the level of groin and axilla. Study conducted by a group of workers on scrotal temperature in other perspective did not find much difference, though significant difference was seen among infertile patients [42].

We are of the opinion that the release of heat by scrotal skin is a quick process. One may not be able to get correct temperature by measuring it from skin. We further propose to measure the temperature in immediate surrounding of scrotum by a very sensitive instrument, thermister (thermal resistor) with an accuracy of ±0.001 °C.

Considering the above,

1. In a group of normal healthy adults (18–40 yr) showing normal semenogram scrotal skin as well as its surrounding temperature is studied.
2. In a group of prepubertal boys (8–12 yr) similar study is conducted and the values are compared with that of normal adults. As per the present hypothesis, scrotal temperature will be lower before the commencement of sperm production.
3. A group of normozoospermic (average count of three samples) subjects (18–40 yr) are divided into subgroups as per their sperm count (20–40; >40 up to 60; >60 up to 80; >80 up to –100; >100 up to 120; and >120 million per milliliter) and their scrotal skin and its surrounding temperature are compared among subgroups. According to the present hypothesis, there should be an increase in temperature as sperm production (in terms of its count) increases.
4. Similar study is conducted in a group of patients where testicular biopsy shows no initiation of sperm production. According to the present hypothesis, temperature in these patients will be lower than the normal group.
5. In a group of healthy volunteers scrotal skin and its surrounding area temperatures are to be recorded in all seasons. These should be correlated with sperm counts in respective seasons. According to the hypothesis the sperm count and the temperature in scrotal skin and surrounding area will be more during winter to give enough temperature to the body.

In experimental animals, the following are to be conducted.

1. The report shows that sperm production is more during winter than summer in some animals like ram, bull and boar [40]. Study the temperature (scrotal and surrounding area) during different seasons, in these animals and correlate with sperm count.
2. During hibernation, activities are minimal for conservation of energy. Testicles are withdrawn to abdomen during hibernation. This may be to utilize the heat available from limited sperm production. If it remained in scrotum it could be dissipated easily. In a group of hibernating animals the scrotal skin and its surrounding temperatures are measured before, during and after the hibernation period. The results of three periods are compared.
3. In animals where intraabdominal testes are present, the testicular and abdominal temperature is measured (a) before and (b) after transplanting testis outside the abdominal cavity.The difference in intraabdominal as well as core body temperature can easily be explained in terms of the hypothesis.

Conclusion

As a conclusion the hypothesis states that a large amount of heat is liberated during sperm production. The heat is liberated well by scrotal skin. This is a part of body thermo regulation. Whenever body is exposed to cold environment testicles are brought close to the body for giving heat. Like wise scrotal muscles are relaxed permitting release of large amount of heat from the body, during exposure to warm climate. Scrotal skin is organized for the same.

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