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Original Research Article

An Anatomical Study on Testicular Descent and Gubernaculum in Human Foetuses

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ABSTRACT

Descent of the testis from an intra-abdominal site in foetal life to scrotum is a mandatory developmental process to ensure that the normal spermatogenesis is established. Key anatomical event with regard to this is the thickening of the gubernaculum and regression. The objective of the study is to determine the timeline of descent of the testes vis-a-vis gubernaculum development and regression in human foetuses between 14 to 40 weeks.

Materials and methods: The structural changes, the attachment of gubernaculum and testicular descent was observed in 30 aborted human foetuses of different gestational ages.

Results: At 14 weeks testes were located at the abdomen near the deep inguinal ring. At 20-24 weeks the location of testis was above the inguinal ring and remained undescended or abdominal. At this stage was the change in the gubernacular structure was the most striking feature. The gubernaculum appeared as thick and bulky with testis adorned as a knob on its summit. Gubernaculum was cranially attachment to the lower pole of testes, epididymis and distally attached to inguinal canal and extended to scrotum, pubic bone and regressed at latter weeks .Testes were observed to migrate through inguinal canal during 26 to 28 weeks. After 32 weeks the testes were in the scrotum and gubernaculum was regressed.

Conclusion: The testicular descent commences at 14 weeks. The testes migrate through inguinal canal from 26 to 28 weeks and descend to the scrotum after 32 weeks of gestation. Gubernaculum was seen to undergo noteworthy structural modifications during descent

Key words: Testicular descent, Gubernaculum

INTRODUCTION

In recent times much significance has been given to testicular descent with reference to different anatomical, physiological and hormonal factors aiding it. Gubernaculum has been the core of many of these studies, to know its function and contribution towards this physiological event and interestingly it always remained to have a history of controversy surrounding it. The descent of testis from abdomen to scrotum is a great example for sexual dimorphism, were anatomical factors and hormones orchestrate to influence this multi-staged event. When testes fail to reach scrotum then it is described as undescended testes. In such cases spermatogenesis is affected as the process requires lower body temperature which is provided by scrotum and results in subsequent infertility. Furthermore high incidence of malignancies is reported in such cases. [1,2] However the extent of damage depends upon location and period of retention. Thus study of testicular

descent is required to understand the causes of cryptorchidism and infertility

The gonads are developed from three different components: the coelomic epithelium, the primordial germ cells and subjacent mesenchyme of the mesonephric bridge. [3] Testes develop on the anteromedial surface of the mesonephros in the urogenital ridge which is anchored by two anatomical structures; the cranial suspensory ligament and the gubernaculum. In most mammals during evolution male gonads assumes an extra-abdominal position within the scrotum. [4] With foetal growth the testes migrate from abdomen to scrotum. The scrotum provides testis the low temperature environment which aides for the physiological functioning of the organ. [5] The exact period for testicular descent is controversial. The testicular migration is believed to begin at 17 weeks of gestation. [6-8] The process accelerates at 24-26 weeks. [6] However Buckhouse reports that it begins by 24th week. [9] The next phase in testicular descent is migrating through inguinal canal to scrotum. At 26-28 weeks of gestation the testes passes through deep inguinal ring, believed to be assisted by gubernaculum and reach the inguinal canal. The descent through inguinal canal to scrotum takes only few days to complete. From 28 weeks testes migrates from superficial inguinal ring to scrotum, its destination. [6]

Over the centuries many conflicting theories have emerged to explain testicular descent, these theories rested on the concept that testis being either pulled or pushed from abdomen to scrotum. One of the most popular theory is, the theory of propulsion as stated by Heyns. [7] Many researchers believes that the increased intra-abdominal pressure during the foetal growth as the main reason for testicular descent, [10] and some believe it has a supplementary role in inguinoscrotal descent. [11] Bowel distension by meconium, closure of physiological hernia, maternal, foetal and pituitary gonadotrophins, and testosterone produced by foetal testis are multiple factors believed to contribute for aiding the descent. [10,12-14] Engle suggested that descent could be the result of closure of deep inguinal ring and simultaneous growth of testis which forces it to move out of the inguinal canal. [15]

The counter theory states that testes are pulled from the abdomen to scrotum. This concept gives rise to traction theory as suggested by Heyns. [7] The role of gubernaculum is a highly discussed topic with regard to this theory. It was John Hunter (1762) a Scottish surgeon who first described gubernaculum, a structure that connects the testis with the scrotum which is required to exert a traction for pulling the testis and its possible role in the testicular descent. [7]

The contraction of muscle fibres, striated or non straiated or contraction of connective tissue surrounding it causes the descent. [16-18] The assumption that testis is pulled by the gubernaculum is asserted by its different distal attachments. Hunter has mentioned up to 6 distal attachments of gubernaculum. [10] Lockwood mentioned gubernaculum tails as fibrous bands anchoring the ectopic testes. [17] Cloquet put forward the idea that gubernaculum grows distally and herniates through abdominal wall and as a result loops of cremaster muscle are formed. [9] According to involution theory the atrophy and shrinkage of gubernaculum aids in testicular descent. [12, 19, 20] However Wells suggested that gubernaculum is not necessary for the descent. [21] The enlargement of the distal end of gubernaculum during the transabdominal phase produces the ‘swelling reaction’ which makes the male gubernaculum short and bulgy. On the contrary no such reaction takes place in females where gubernaculum later gives rise to round ligament of uterus. The recent studies suggest that the gubernaculum, is not mere an inert ligament, but actually acquires specific growth properties similar to an embryonic limb bud. [22, 23]

There is disparity regarding the gubernacular caudal and distal attachments. Buckhouse, Hunter, Wensing, Beasley & Hutson observed that gubernaculum is

attached to lower pole of testes and epididymis. [9,10,24,25] Hynes reported that cranially gubernaculum attaches to lower pole of testes, however did not support the emphasis of gubernacular attachment to epididymis. [7] Favorito et al observed that changes in the proximal attachment of the gubernaculum are associated with epididymal anomalies and can contribute to the occurrence of cryptorchidism. [26]

With the complexities in the genesis of testes and the controversies surrounding the supporting theories perhaps an extensive study on gubernaculum and migration of testes may help us to address the clinical abnormalities such as testicular dysgenesis, maldevelopment and associated cryptorchidism as well as enhance our comprehension of testicular migration and the role of gubernaculum in it. In the present study we describe the anatomic changes in the testicular descent with special reference to gubernaculum. The goal is to determine the gestational age specific difference in the position of the testis and the gubernaculum

MATERIALS AND METHODS

30 aborted foetuses without any gross abnormality are collected from MGM Medical College, Department of Obstetrics and Gynaecology, Navi Mumbai and Aurangabad after ethical review and permission from the concerned authorities. The age of foetuses were calculated from the obstetrical history, the crown-rump length and the foot length.

A Para-median incision along the abdominal wall was taken and the flaps were reflected laterally. The testes were observed for their location at different gestational weeks. The gubernaculum was observed for the structural changes as well as its cranial and caudal attachments.

RESULTS

The study focused on the testicular descent and the changes in gubernaculum across the gestation. Testes were considered to be abdominal or undescended when situated superior to the deep inguinal ring and descended when situated inferior to the superficial inguinal ring. On dissection it was found that testes appeared as a gobbet on the apex of jelly like gubernaculum and were freely movable. Testes were covered by peritoneum except on the posterior surface where the testicular vessels entered. It was observed that the testicular vessels and vas deference runs in the testicular mesentery. The upper pole of testes was anchored by cranial suspensory ligament which gradually regressed as the testes entered the inguinal canal. Gubernaculum extended from the lower pole of the testes, as well as from epididymis, beginning of vas deferens to the developing inguinal canal and in some cases it extended to the pubic bone.

At 14 weeks testes were located in the groin above the deep inguinal ring. The gubernaculum was seen as a white cord like structure extending from the lower pole of testis to the developing inguinal canal and in few foetuses it extended to the pubic bone. No gubernacular extension was observed in perineal/saphenous or femoral area. At this stage testis had its own mesentery. Wolffian duct was found to enter the developing urinary bladder posteriorly (Fig.1 A). At 16 weeks testes were still abdominal, in the groin to be specific and above the deep inguinal ring. The gubernaculum though appeared to be thicker than the previous weeks.

Table 1: Showing the location of testes at different gestational weeks

Gestational weeks (No. of foetuses)	Abdominal	Inguinal	Scrotal
14 (1)	1	-	-
16 (3)	3	-	-
18 (6)	6	-	-
20 (3)	3	-	-
22 (4)	4	-	-
24 (2)	2	-	-
26(1)	-	1	-
26(3)	3	-	-
28 (1)	-	1	-
32 (1)	-	-	1
35 (1)	-	-	1
36 (1)	-	-	1
40 (3)	-	-	3

Table 2: Showing Gubernacular attachment and presence of gubernaculum swelling at different gestational weeks

Gestational weeks (No of foetuses)	Cranial attachment	Caudal attachment	Gubernaculum Present /Absent	Additional attachment	Gubernaculum reaction/swelling (No. of Foetuses)
14-20 (13)	Lower pole of testes, epididymis	Inguinal canal	Present	Pubic bone , extension to inguinal canal	0/13
22 (4)	Lower pole of testes, epididymis	Inguinal canal	Present	Pubic bone , extension to inguinal canal	¼
24 (2)	Lower pole of testes, epididymis	Inguinal canal	Present	Pubic bone , extension to inguinal canal	2/2
26 (4)	Lower pole of testes, epididymis	Inguinal canal	Present	Pubic bone , extension to inguinal canal	4/4
28 (1)	Lower pole of testes, epididymis	Inguinal canal	Present	Pubic bone , extension to inguinal canal	1/1
32 (1)	Weak attachment to lower pole of testes, epididymis	Weak attachment to inguinal canal	Present, very thin strands of gubernaculum appreciated	Pubic bone , extension to inguinal canal	0/1
35 (1)	No attachment appreciated	very thin strands of gubernaculum present	Absent (Regressed)	No additional attachment	0/1
36 (1)	No attachment appreciated	No attachment appreciated	Absent (Regressed)	No additional attachment	0/1
40 (3)	No attachment appreciated	No attachment appreciated	Absent (Regressed)	No additional attachment	0/3

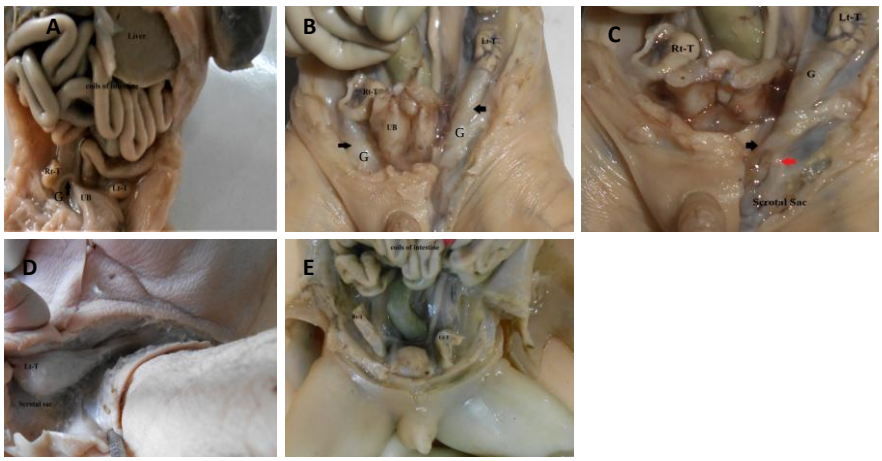

Fig.1 **A** Human foetus at 16 weeks. Arrow shows Wolffian duct entering developing urinary bladder posteriorly. **B** Human foetus at 24 weeks. Left testis (Lt-T) is situated higher than the right testis (Rt-T). The arrows show the right and left gubernaculum extending from testes to inguinal canal. Gubernaculum appears thick and bulky at this week. **C** Human foetus at 24 weeks, picture shows gubernacular attachment in inguinal canal. The black arrow shows gubernaculum extension towards pubic bone, and red arrows shows its extension to scrotal sac. **D** Human foetus at 40 weeks. Left testis (Lt-T) is located in the scrotal sac. Gubernaculum is found to be regressed at this gestational week. **E** Human foetus at 26 weeks. Picture showing right testis (Rt-T) located higher than left testis (Lt-T) (Rt-T=Right testis, Lt-T=left testis, UB-Urinary bladder, G-Gubernaculum

At 20-24 weeks the location of testis was above the inguinal ring and remained undescended /abdominal. But the remarkable feature at this stage was the change in the gubernacular structure. The gubernaculum appeared as thick and bulky with testis adorned as a knob on its summit (Fig.1 B). At this stage extension from gubernaculum to pubis and developing scrotum was appreciated (Fig.1 C). Testicular descent was observed as a slow and progressive event from 14-24 weeks as testes remained abdominal and gradually approaches the deep inguinal ring. By 24-26 weeks they appeared just above or in the deep inguinal opening. For further observation the inguinal canal was dissected at 24 and 26 weeks and it was found to be

short with both the openings close to each other. The canal contained the gubernaculum and in some cases its extensions reached the pubic bone. Testes passed through the deep inguinal ring and canal from 26-28 weeks. Prior to descent it was observed that there was an increase in gubernacular length. In foetuses ranging from 26-28 weeks 60% had testes in inguinal canal and 40% had it in between the inguinal canal and scrotum. The passage of testis from inguinal canal to scrotum began from 28th week onwards. Testes of all the foetuses from 32nd week had descended to scrotum. At 38 to 40 weeks the testes were in the scrotum and gubernaculum got regressed ((Fig.1 D). In some cases right and left testes showed little difference in their location. In 4% cases (18-25 weeks) left testis was found to be little higher than the right testis (Fig.1 B) and in 6% cases (16-26 weeks) vice versa (Fig.1 E).

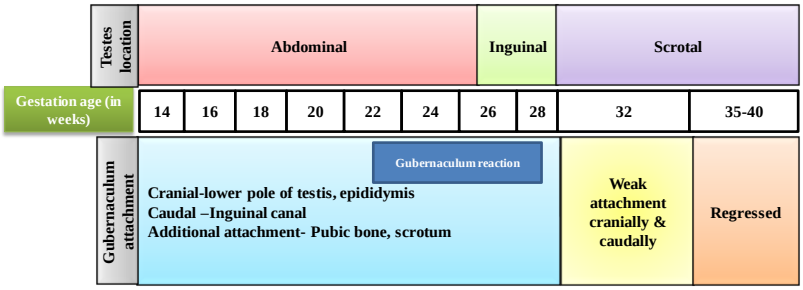

Fig : 2 Time line for testicular descendent vis-a-vis anatomical changes in gubernaculum during human fetal development. Upper boxes represent position of the testis at that fetal gestational age (in weeks). Lower boxes represent the gubernaculum attachments and the timeline for its regression. As evident gubernaculum reaction (swelling and bulging) occurs between 22 to 28 weeks of gestation and its weakening occurs when the testis is in the inguinal region and precedes the scrotal descendent. Gubernaculum is completely regressed only when testis is in the scrotum.

DISCUSSION

Testicular descent still intrigues researchers around the globe despite the extensive work done on it. The driving force behind may be the disparity among the theories proposed to explain this nexus of well coordinated event which looks so simple superficially yet is not. The disagreement still rest on the contribution of mechanical and hormonal factors aiding the descent, attachment of gubernaculum and the changes it undergo and its significance during this event.

Two phase testicular descent is a widely accepted theory and is regulated by different anatomical and hormonal factors.1) Transbdominal phase occurs at 10-15 weeks of gestation in humans and 13-17 gestational days in rodents. After completion of 1st phase there is a pause in testicular migration about 25 weeks of gestation in humans. 2) Inguinoscrotal phase occurs from 25 weeks to 40 weeks of gestation in humans. This phase is more complex than the earlier one as it involves series of gubernacular changes.

The present study confirms the observation by Buckhouse, Hunter, Wensing, Beasley & Hutson regarding the gubernaculum attachment, that it is firmly attached to lower pole of testes, epididymis and beginning of vas deferens and they descend as a single entity. [9,10,24,25] Hynes reported gubernaculum attached to the lower pole of testes but did not support the emphasis of its epididymis attachment. [7] However the present study does not support the findings of Wyndham, Hart, Wells and Hadziselimovic &Kriuslin which emphasised that the gubernaculum is attached to the epididymis and not directly to testes. [18,20,21,27] In the present study it was found that the gubernaculum was attached to inguinal canal and extended to the developing scrotum but in later gestational weeks it regressed. Cleland,

Wells, Scorer and Hadziselimovic reported that there is no extension of the gubernaculum into the bottom of the scrotum. [19,21,28,29] In the present study the gubernaculum is found to extend to pubic bone. However no extensions to saphenous area, femoral canal, root of penis and perineum was found as emphasised by Schechter (quoted in Rajfer & Walsh,), Lockwood, Wyndham, Lemeh, and Rajfer. [12,17,18,30,31] The present study is in agreement with the findings of Heyns, Buckhouse, Hart and that there is a preformed inguinal canal with gubernacular extension present in it. [7,9,20] In the present study it was found that the gubernaculum which had strong attachment to inguinal canal regressed after the inguino-scrotal phase. This finding is in accordance with the findings of Hunter, Wyndham, Scorer and Keith who reported that the gubernaculum attenuates after the descent to the scrotum. [10,18,28,32] In the present study it was observed that gubernaculum undergoes some significant morphological changes during the descent. There is an increase in gubernacular length prior to descent observed in the present study which is in accordance with the findings of Heyns, Lockwood. [7,17] In the present study the gubernaculum showed thickening and bulging, during 20-24 weeks. Similar observations were made by Heynes and Buckhouse. [7,9] Obscurity still remains regarding the exact time period of the testicular migration. In the present study it was found that at 14 weeks testes were located in the groin above the deep inguinal ring which clearly indicates that the descent had commenced. At 14-20 gestational weeks all the testes were abdominal, above or near to the deep inguinal ring. These findings are in accordance with observations of Heyns, Sampaio & Favorito. [7,8] Whereas our study does not support the observations of Buckhouse, Hunter, Wyndham and Lemeh who reported that the descent appeared at latter stages of gestation. [9,10,18,30] In the present study testes were found to be abdominal from 14-25 weeks of gestation. Out of 4 cases at 26 weeks of gestation, in 1 case testes were present in inguinal canal. In the present study testes were found in the scrotum from 32 weeks onwards. This finding is in accordance with the observations of Heyns, Buckhouse, while Luciano et al reported that testes descended to scrotum after 30 weeks of gestation. [7,9,33] Heyns reported that 75 % of the testes passed through the inguinal canal in the period between 24 and 28 weeks. [7] In the present study in 4% cases (18-25 weeks) left testes was found to be little higher than the right testes and in 6% cases (16-26 weeks) vice versa. Scorer noted that descent takes place a little later on the left than on the right and Heyns observed left testis had descended prior to the right in 70% of the cases with asymmetrical descent. [7,34,35]

In our study the significant changes such as, lengthening, bulging, shortening and degeneration in the gubernaculum at different gestational ages shows that the role of gubernaculum is undeniable in testicular descent. Since developmental events are highly tuned in nature it is possible that some of the event may have been misinterpreted due to lack specimens available in earlier studies. To address some of these problems, in the present study we systematically performed anatomical studies on foetuses obtained as early as 14 weeks of gestation until 40 weeks. Special care was taken to have adequate representation of foetuses at every fortnightly interval. We believe that such fine time course analysis would help us to have a clear understanding of the dynamics of gubernaculum development and testicular descent.

CONCLUSION

Testicular migration occur in two phases, transabdominal and inguino-scrotal. In the first phase testes migrates from abdomen to inguinal canal and in second phase testes migrates from inguinal canal to scrotum. In the present study which had foetuses ranging from 14 weeks to 40 weeks, descent commenced at 14 weeks,

where testes was located above the deep inguinal ring. The migration through the inguinal canal occurred from 26-28 weeks. Testes were located in the scrotum after 32 weeks of gestation. Gubernaculum is a very important mechanical aid for testicular descent. Gubernaculum was seen to undergo noteworthy structural modifications during descent such as lengthening, shortening, bulging (gubernaculum reaction) and eventual degeneration. Gubernaculum had cranial attachment to the lower pole of testes, epididymis and beginning of vas deferens. Distally gubernaculum was attached to inguinal canal and extended to scrotum but regressed as testes migrated to the scrotum. It was observed that there were extensions of gubernaculum to the pubic bone. Testicular descent is without a doubt is a complex process staged by the influence of multiple factors playing synchronously and more extensive studies on anatomical as well as hormonal factors regulating them need to be carried out for the better comprehension of the event.

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