Histogenesis of Human Fetal Renal Cortex

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Research Article

Abstract: Histogenesis of human fetal kidney throws light upon the histological maturity of kidney and its functional status at a given gestational age. Kidney develops from two sources, ureteric bud and metanephric blastema. Ureteric bud differentiates into the collecting part i.e. collecting tubules and ureter while the metanephric blastema forms secretory part i.e. nephron. Both these parts get fused with each other so as to complete the development. The present study was carried out on 50 aborted human fetuses between 13-36 weeks of gestational age with no obvious congenital anomalies. Cut sections of both kidneys were processed and paraffin blocks prepared. Sections of 5-7 micron thick were taken, mounted and stained with Haematoxylin and Eosin, Masson's trichrome and Periodic acid-schiff stains. Microscopic features were observed and documented. The kidney showed lobulations which fused completely at 16 weeks, histologically. Nephrogenic zone was seen up to 32 weeks. The glomeruli passed through various stages of development from vesicular to mature form. The primitive forms of glomeruli were seen in the superficial part of the cortex while the most mature of them were seen in the deeper part of the cortex. Vascularity of glomeruli increased with increase in gestational age. With increase in gestational age, Bowman's capsule became well differentiated. The proximal and distal convoluted tubules were identified in cortex from 16th week onwards. Cortico-medullary differentiation was well pronounced from 16-18 week onwards.

Keywords: Kidney, renal cortex, gestational age, ureteric bud, metanephric blastema, nephrogenic zone.

Introduction

The development of fetus begins with the formation of zygote and it proceeds to form various germ layers from which all the organ systems develop. It is important to know the normal developmental gross and microanatomy of the urinary system for better understanding of various congenital anomalies. The fetal kidney is a lobulated organ, presenting about 12 lobes. In adults, the kidneys show a smooth surface due to fusion of the fetal lobes, although traces of lobulation may persist [1]. The internal macrostructure of the kidney can be divided into an inner medulla and outer cortex. Microscopically the kidney consists of many tortuous uriniferous tubules, bounded by a delicate connective tissue in which blood vessels, nerves and lymphatics lie. Each tubule consists of two embryologically distinct parts, the nephron, developing from metanephric blastema, which produces urine, and the collecting part, developing from ureteric bud, comprising of collecting ducts, renal calyces, pelvis and ureter [1,2]. Metanephros, the primordia of permanent kidneys, appear in lumbosacral regions and begin to develop in 5th week while its functioning starts approximately 4 weeks later [2]. Since the beginning of 19th century, work has been done on structural development of kidney. Bowman [3] thought that during development of renal corpuscle, the Bowman's capsule was perforated by afferent and efferent vessels. Gerlach [4] stated that when capillaries penetrated the capsule, they must push capsular cells ahead of them instead of breaking through, as Bowman assumed. According to Helena Maria et al [5], nephrogenesis in human starts at 6th week of intrauterine life and completes by 35th week of gestation. After 25 weeks, glomeruli forms cortical layer making cortico-medullary differentiation more distinct. The differentiating tubules are numerous between 25 to 30 weeks period.

Materials and Methods

The present study titled "Study of histogenesis of human fetal renal cortex" was carried out in the Department of Anatomy, Government Medical College, Aurangabad, Maharashtra, India. 50 aborted human fetuses (29 females and 21 males) between 13-36 weeks of gestational age were obtained from the Department of Obstetrics and Gynaecology of the same institute after taking prior permission of the Head of the Department and written consent from the parents. The study was approved by the institutional ethics committee. The specimen fetuses were the ones with spontaneous abortions, stillborns and those terminated under the Medical Termination of Pregnancy Act, India. Twins and fetuses with gross congenital anomalies were excluded from the study. The aborted fetuses were fixed by injecting 10% formalin in the thoracic and abdominal cavity and kept in 10% formalin jar and dissected within 2 hrs of collection. A midline vertical incision was taken on the anterior abdominal wall, abdominal cavity opened and both kidneys removed. Longitudinal sections (L.S.) of the right and left kidneys were taken in such a way that it included cortex, medulla and hilum, each section being

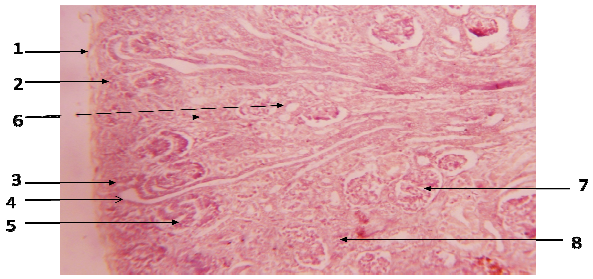
3-4 mm thick. Specimens were kept in Bouin's fluid for 4-5 days. The blocks were labeled and prepared for cutting. The blocks were cut, 5-7 micron in thickness in the form of ribbon with the help of a rotary microtome. Sections were then stained with the Haematoxylin and Eosin (H & E), Masson's trichrome (MT) and Periodic acid-schiff (PAS) stains. Histogenesis of the kidney was then studied by examining the slides prepared, under low and high power of light microscope.

Observations and Results

At 13 weeks:

1) Haematoxylin and eosin stain (H & E):

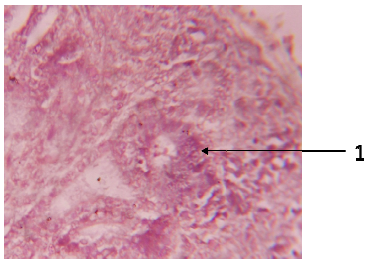
As shown in Photomicrograph 1, the kidney was found to be covered by a thin capsule made up of fibrous tissue. Beneath the capsule, the kidney was divided into cortex and medulla. Lobulations were seen in the superficial part of the cortex. They were fused with each other in the deeper part of the cortex. A wide zone of undifferentiated mesenchymal tissue was found just beneath the capsule in the superficial part of the cortex. This was the nephrogenic zone, containing nephrogenic cells (photomicrograph 1). Beneath the capsule, ampulla of the growing and dividing ureteric bud was seen in the nephrogenic zone. This dividing ureteric bud was lined by cuboidal epithelium with centrally placed nuclei and surrounded by a group of nephrogenic cells, forming a cap over the ampulla (photomicrograph 1).



Photomicrograph 1: Kidney (cortex); LS; 13 weeks; H&E; 10X
(1.Capsule, 2. Nephrogenic zone, 3. Nephrogenic cells, 4. Ampulla 5. 'S' shaped tubule, 6. Developing tubules, 7. Developing renal corpuscle, 8. Mesenchymal tissue)

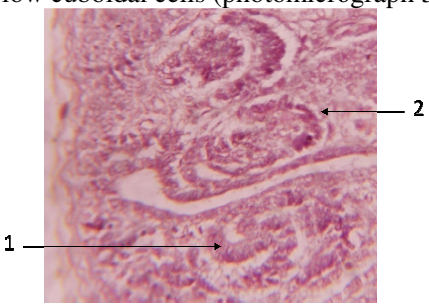
Deep to the nephrogenic zone, developing renal corpuscles were seen (photomicrograph 1). These were dispersed within the parenchyma and showed the following different developmental stages.

Stage I: In the superficial part of the cortex, the growing ureteric buds were seen dividing dichotomously to form new tubules. Some cells in the form of groups were seen at an angle between the growing ampulla and old tubule. These cells formed hollow structures lined by single layer of cells, having central cavity (photomicrograph 2). These were renal vesicles, representing the most primitive forms of glomeruli.



Photomicrograph 2: 13 weeks; H&E; 40X
(1. Renal vesicle)

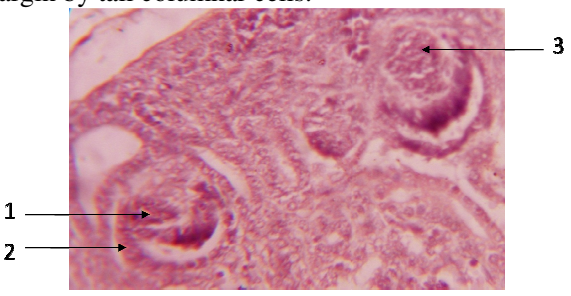
Stage II: 'S'- shaped hollow tubular structure was seen at some places, lined by a single layer of cells. It had three portions; upper closer to the capsule, lower towards the medulla, and the middle between the two. The outer wall of lower portion with concave margins was lined by tall columnar cells and the inner wall having convex margin by low cuboidal cells (photomicrograph 3).



Photomicrograph 3: 13 weeks; H&E; 40X
(1. 'S'- shaped tubule, 2. Lower portion of 'S'- shaped tubule)

Stage III: The lower portion of the 'S'- shaped tubule appeared crescentic in some developing renal corpuscles (photomicrograph 4). The mesenchymal cells were loosely arranged within the concavity of the crescent shaped Bowman's space. The cells of the lower convex margin of the crescent were flattened to low cuboidal. The upper portion joined with the growing ureteric bud (photomicrograph 3).

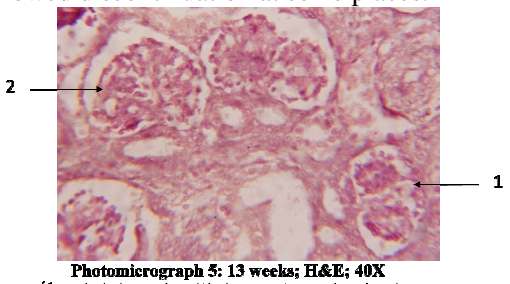
Stage IV: The developing capillaries were found to invaginate the crescent in some developing renal corpuscles (photomicrograph 4). The convex margin of the crescent was lined by flat cells while the concave margin by tall columnar cells.



Photomicrograph 4: 13 weeks; H&E; 40X
(1. Mesenchymal cells, 2. Crescentic Bowman's space, 3. Capillary invagination in crescent)

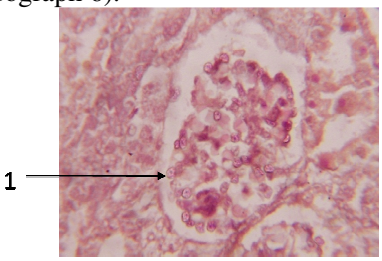
Stage V: Lobulations were seen in the glomerular capillaries within the crescentic Bowman's capsule at some places (photomicrograph 5). The convex and concave margin of the crescent became parietal and visceral layers of Bowman's capsule respectively.

Stage VI: Well marked lobulations were seen in the glomeruli located in the deeper aspects of the superficial cortex (photomicrograph 5). The visceral epithelium was formed by closely packed columnar to cuboidal cells but showed discontinuation at some places.



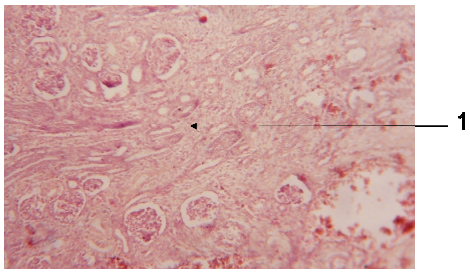
Photomicrograph 5: 13 weeks; H&E; 40X
(1. Lobulations of capillaries, 2. Glomerulus showing well marked lobulations)

Stage VII: Network of glomerular capillaries was seen in the Bowman's capsule. The visceral layer of the Bowman's capsule showed few cells, scattered over the surface of the glomerular tuft. The parietal layer was lined by squamous cells. These were the mature renal corpuscles present in the deeper aspect of the cortex (photomicrograph 6).



Photomicrograph 6: 13 weeks; H&E; 40X
(1. Mature renal corpuscle)

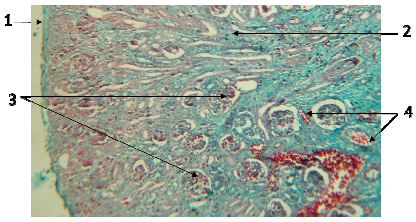
Over all, immature glomeruli were seen in the superficial part of the cortex while the mature one's with lobulated capillaries in the deeper part. The immature developing glomeruli were more in number as compared to the mature one's (photomicrograph 1). Some developing tubules were seen in between the developing glomeruli. These tubules were lined by cuboidal cells with pale eosinophilic cytoplasm and vesicular nuclei (photomicrograph 1). These tubules could not be differentiated into proximal convoluted tubules (PCT) or distal convoluted tubules (DCT). In between the tubules and glomeruli, the mesenchymal connective tissue was seen (photomicrograph 1). The beginning of the differentiation of the cortico-medullary junction was appreciated but wasn't well marked (photomicrograph 7).



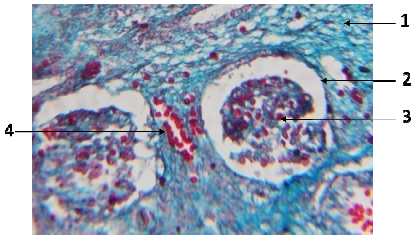
Photomicrograph 7: 13 weeks;H&E;10X
(1. Cortico-medullary Junction)

2) Masson's trichrome stain

Capsule stained green. Mesenchymal connective tissue stained green and was found to be abundant (photomicrograph 8). The basement membrane of lining epithelium of parietal layer of Bowman's capsule stained green (photomicrograph 8) or blue (photomicrograph 9), depending upon counter stain used. At this stage, glomerulus stained faint red because of less vascularity. RBCs in blood capillaries stained red (photomicrograph 9).



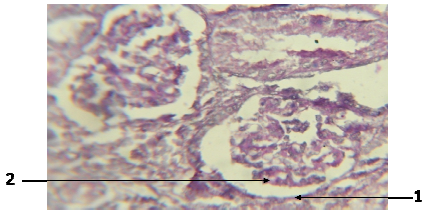
Photomicrograph 8: 13 weeks; MT; 10X
[1. Capsule (stained green), 2. Mesenchymal tissue (stained green), 3. Less vascular glomerulus (faint red), 4. RBCs in capillaries (stained red)]



Photomicrograph 9: 13 weeks; MT; 40X
[1.Mesenchymal tissue (stained blue), 2. Parietal layer of Bowman's capsule (stained blue), 3. Less vascular glomerulus (faint red), 4. RBCs in capillaries (stained red)]

3) PAS stain:

The basement membrane of lining epithelium of parietal and visceral layer of Bowman's capsule stained faint magenta in colour (photomicrograph 10).

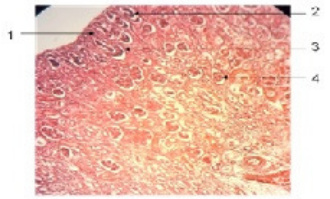


Photomicrograph 10:13 weeks; PAS; 40X
(1. Parietal layer of Bowman's capsule,
2. Visceral layer of Bowman's capsule)

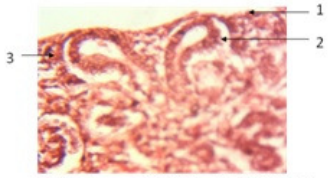
At 16 weeks

1) Haematoxylin and eosin stain (H & E):

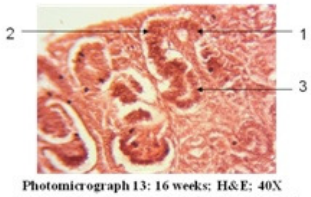
Microscopically, the lobules appeared to be fused with each other, but grossly, could still be seen on the surface of the kidney. The nephrogenic zone with undifferentiated nephrogenic cells was seen but was reduced in thickness as compared to the previous stage (photomicrograph 11). Growing ureteric bud dividing dichotomously was seen (photomicrograph 12). The developing renal corpuscles of all stages were seen similar to the previous stage (photomicrograph 11 and 13). More mature glomeruli were located in the deeper aspect of the cortex and were more in number as compared to the previous stage (photomicrograph 11). At this stage, the tubules were identified as PCT and DCT in the deeper part of cortex according to their characteristic presentation. Tubules with larger cells and intensely eosinophilic cytoplasm with brush border and rounded nuclei were the proximal convoluted tubules. Others with wider lumen and lined by simple cuboidal cells with pale eosinophilic cytoplasm and rounded nuclei were the distal convoluted tubules (photomicrograph 14). The Juxta-glomerular apparatus (JG) was observed (photomicrograph 14). The amount of mesenchymal connective tissue was reduced. Differentiation between cortex and medulla was well marked than the previous stage.



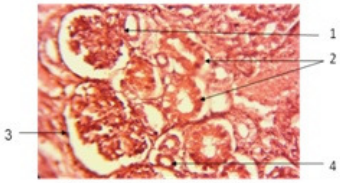
Photomicrograph 11: 16 weeks; H&E: 10X
(1. Nephrogenic zone, 2. 'S' shaped tubule, 3. Crescentic Bowman's capsule, 4. Maturing renal corpuscle)



Photomicrograph 12: 16 weeks; H&E: 40X
(1. Capsule, 2. Ampulla of dichotomously dividing ureteric bud, 3. Nephrogenic cells around ampulla)



Photomicrograph 13: 16 weeks; H&E: 40X
(1. Ampulla, 2. Upper portion of 'S'-shaped tubule 3. Lower portion of 'S'-shaped tubule)



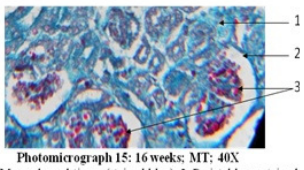
Photomicrograph 14: 16 weeks; H&E: 40X
(1. JG apparatus, 2. PCT, 3. Stage VI renal corpuscle, 4. DCT)

2) Masson's trichrome stain

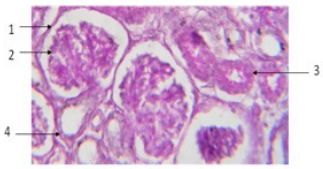
Capsule stained blue, mesenchymal connective tissue blue and was reduced than the previous stage. Glomeruli stained deeply with red colour, indicating its increased vascularity (photomicrograph 15).

3) PAS stain

The basement membrane of lining epithelium of parietal and visceral layers of Bowman's capsule stained deep magenta in colour, indicating the better differentiated Bowman's capsule as compared to the previous stage. Likewise, basement membrane of lining epithelium of PCT and DCT stained magenta in colour (photomicrograph 16).



Photomicrograph 15: 16 weeks; MT; 40X
[(1. Mesenchymal tissue (stained blue), 2. Parietal layer stained blue, 3. Increased vascularity of glomerulus (more red)]

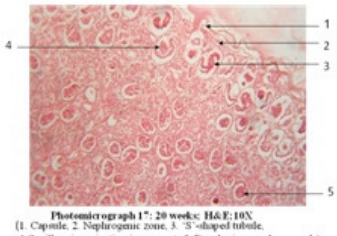


Photomicrograph 16: 16 weeks; PAS: 40X
(1. Parietal layer of Bowman's capsule, 2. Visceral layer of Bowman's capsule, 3. Basement membrane of PCT, 4. Basement membrane of DCT)

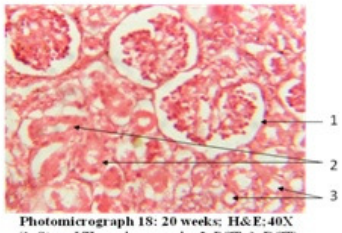
At 20 weeks

1) Haematoxylin and eosin stain (H & E):

Beneath the capsule, the nephrogenic zone appeared reduced in thickness as compared to the previous stage. The cortex appeared more mature with increased thickness. The number of mature glomeruli increased and were present in the deeper part of the cortex however only a few developing glomeruli were seen in the superficial part of the cortex (photomicrograph 17). At higher magnification, more number of PCT and DCT were easily identified with their characteristic staining patterns (photomicrograph 18).



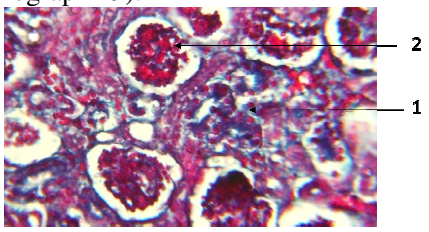
Photomicrograph 17: 20 weeks; H&E:10X
(1. Capsule, 2. Nephrogenic zone, 3. 'S'-shaped tubule, 4.Capillary invagination in crescent, 5. Developing renal corpuscle)



Photomicrograph 18: 20 weeks; H&E:40X
(1. Stage VII renal corpuscle, 2. PCT, 3. DCT)

2) Masson's Trichrome stain

Mesenchymal connective tissue appeared less than the previous stage. Glomeruli stained deep red in colour and were distinctly seen than the previous stage (photomicrograph 19).



Photomicrograph 19: 20 weeks; MT; 40X
[1. Mesenchymal tissue (stained blue),
2. Increased vascularity of glomerulus (more red)]

3) PAS stain

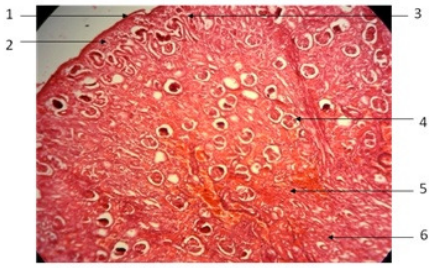
Findings were similar to that of the previous stage.

At 24 weeks

1) Haematoxylin and eosin stain (H & E)

Beneath the capsule, the nephrogenic zone appeared thinner. Growing ureteric bud with ampulla was seen.

Mature glomeruli were located in the deeper part of the cortex (photomicrograph 20). Few developing renal corpuscles at various stages of development were seen in the superficial part of the cortex.

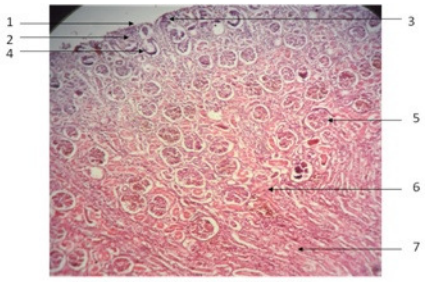


Photomicrograph 20: 24 weeks; H&E;10X
(1. Capsule, 2. Nephrogenic zone, 3. Ampulla, 4. Developing renal corpuscle, 5. Cortico-medullary junction, 6. Medulla)

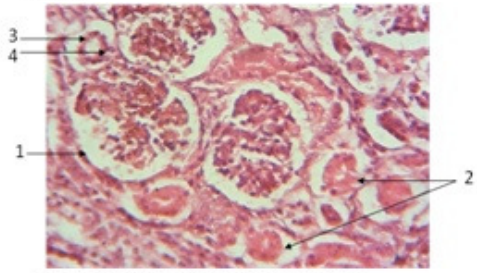
At 32 weeks

1) Haematoxylin and eosin stain (H & E)

The nephrogenic zone appeared as a thin strip beneath the capsule. Ampulla of growing ureteric bud was seen (photomicrograph 21). Very few developing glomeruli were observed in the superficial part of the cortex. The number of mature glomeruli was increased and were present even in the superficial part of the cortex (photomicrograph 21). The PCTs and DCTs were distinctly seen, especially in the deeper part of the cortex. PCTs were more in number than DCTs. The JG apparatus was better differentiated as compared to the previous stage (photomicrograph 22). The cortico-medullary differentiation was more distinct (photomicrograph 21). The thickness of both the cortex and medulla was increased.



Photomicrograph 21: 32 weeks; H&E;10X
(1. Capsule, 2. Nephrogenic zone, 3. Ampulla, 4. Crescentic shaped Bowman's space, 5. Developing renal corpuscle, 6. Cortico-medullary junction, 7. medulla)



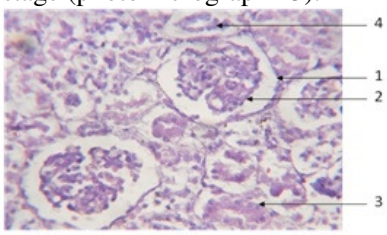
Photomicrograph 22: 32 weeks; H&E; 40X
(1. Stage VII renal corpuscle, 2. PCT, 3. DCT, 4. JG apparatus)

2) Masson's trichrome stain

Findings were similar to that of the previous stage.

3) PAS stain

The basement membrane of lining epithelium of parietal and visceral layers of the Bowman's capsule stained deeply with magenta colour, as a result the Bowman's capsule was better differentiated than the previous stage. Also, basement membrane of the lining epithelium of PCT and DCT stained deeply with magenta colour than the previous stage (photomicrograph 23).

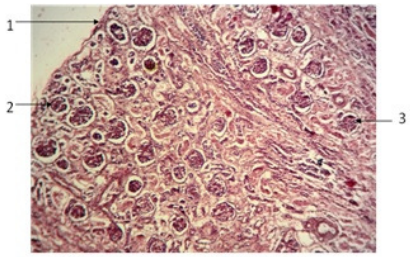


Photomicrograph 23: 32 weeks; PAS; 40X
(1. Parietal layer of Bowman's capsule, 2. Visceral layer of Bowman's capsule, 3. Basement membrane of PCT, 4. Basement membrane of DCT)

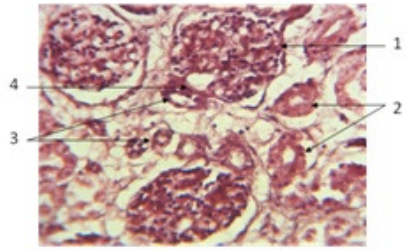
At 36 weeks

1) Haematoxylin and eosin stain (H & E)

Lobulations were still seen on the surface of the kidney. Beneath the capsule the nephrogenic zone was marked by its absence. The glomeruli with well lobulated glomerular tufts were seen beneath the capsule in superficial part of the cortex. In the deeper cortex, more mature forms of glomeruli were seen (photomicrograph 24). The PCTs and DCTs were distinctly seen. The JG apparatus was well differentiated (photomicrograph 25).



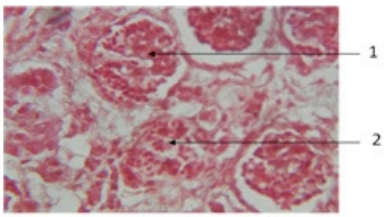
Photomicrograph 24: 36 weeks; H&E; 10X
(1. Capsule, 2. Mature renal corpuscle, 3. Juxta-medullary mature renal corpuscle)



Photomicrograph 25: 36 weeks; H&E; 40X
(1. Stage VII renal corpuscle, 2. PCT, 3. DCT, 4. JG apparatus)

2) Masson's Trichrome

Glomeruli appeared most vascular at this stage and accordingly were stained with deep red colour (photomicrograph 26).



Photomicrograph 26: 36 weeks; MT; 40X
[(1. Increased vascularity of glomerulus (more red).
2. RBCs in capillaries (stained red)]

3) PAS stain

Findings were similar to that of the previous stage.

Discussion

1) H and E staining

a) Kidney Lobulation

In the present study, at 13 weeks of gestation, the kidney showed lobulations separated by deep clefts. At 16 weeks of gestation, the lobules were found to be fused in histological sections, however the lobulation persisted grossly uptill 36 weeks of gestation. Findings of the present study were similar to that of Mishra S et al [6] who observed that, histologically, at 14 weeks the kidney was in a lobulated form but at 16 weeks the lobules appeared to be fused. Tank KC et al [7] found that at 12 and 14 weeks, the lobes were separated only in the superficial part of the cortex, but were fused with each other in the deeper part of cortex. However, according to Syed SA et al [8], lobules appeared to be fused with each other histologically at 18 weeks of gestation.

b) Cortico- Medullary Differentiation

In the present study, the cortico-medullary differentiation was appreciated right from 13 weeks of gestation, initiation could not be commented since non availability of specimens before 13 weeks, and however it was not well marked. At 16-18 weeks, it appeared more distinct and at 36 weeks, was clearly demarcated. According to Helena Maria Lizardo-Daudt et al [5], between 11-15 weeks of gestation, differentiation between cortex and medulla was initiated and completely defined between 25-30 weeks. Mishra S et al [6] documented that the cortico-medullary junction was well defined at 18-20 weeks of gestation. Tank KC et al [7] stated that, at 12 weeks, the cortico-medullary junction was not well differentiated. At 24 weeks the cortico-medullary junction had become more distinct. Syed SA et al [8] described that the cortico-medullary differentiation became more distinct at 24 weeks of gestation. Patil S et al [9] observed that, from 23rd week onwards, the cortico-medullary differentiation became more distinct.

c) Nephrogenic zone

In the present study, the nephrogenic zone was observed beneath the capsule from 13 to 32 weeks of gestation. At 13th week, this zone was thick and formed a broad band beneath the capsule. Thereafter the thickness gradually decreased. At 36 weeks of gestation, the nephrogenic zone was not seen. Our findings were more or less comparable with most of the following studies. According to Helena Maria Lizardo-Daudt et al [5], the nephrogenic tissue was abundant during 6-10 weeks of gestation and disappeared between 35-37 weeks of gestation. Daković-Bjelaković M et al [10] observed that, at 13th week of gestation, just below the renal capsule, there was a wide nephrogenic zone, which thinned out at 23rd week. At the end of nephrogenesis, the nephrogenic zone disappeared completely. Mishra S et al [6] quoted the persistence of nephrogenic mesenchymous tissue at the periphery of cortex at 28 weeks of gestation. Tank KC et al [7] stated that, at 12th week of gestation, nephrogenic zone was seen, containing nephrogenic cells and at 36 weeks, no such zone beneath the capsule was observed. Syed SA et al [8] found that, at 14th week of gestation, just beneath the capsule, the nephrogenic zone was seen containing nephrogenic cells. At 37- 40 weeks of gestation, the subcapsular nephrogenic zone disappeared. Patil S et al [9] described that, at 16th week stage, the nephrogenic zone was seen just beneath the capsule, which disappeared at 38 weeks of gestation.

d) Ampullary growth

In the present study, the ampullas of growing ureteric buds, lined by cuboidal cells and surrounded by nephrogenic tissue were seen in the superficial part of the cortex beneath the nephrogenic zone up to 32 weeks of gestation. Daković-Bjelaković M et al [10] found that, at 13th week of gestation, nephrogenic zone contained terminal ends of ureteric bud. Tank KC et al [7] and Syed SA et al [8] observed the growing ureteric bud in the form of ampulla beneath the nephrogenic zone at 14th week of gestation.

e) Renal corpuscles

In the present study, the following stages of glomerular development were seen.

Stage I – vesicular form, Stage II – 'S'-shaped form, Stage III – crescentic, Stage IV - developing capillaries invaginating the crescent. Stage V- lobulations in the glomerular capillaries within the crescentic Bowman's capsule. Stage VI- well marked lobulations in the glomeruli located in the deeper part of the superficial cortex. Stage VII- network of glomerular capillaries in the Bowman's capsule. In the present study, the various developmental stages of glomeruli described above were seen in every histological section studied from 13th to 32nd week. The initial stages of developing glomeruli (stage I to stage IV) were observed in the superficial part of the cortex while later stages (stage V to stage VII) were located in the deeper part of cortex thereby indicating the direction of maturation from superficial to deep cortex. Helena Maria Lizardo-Daud [5] quoted that

the rudimentary glomeruli were numerous between 6-10 weeks of gestation, after which their number diminished. Between 25-30 weeks, more mature glomeruli were seen and at 35-37 weeks of gestation, rudimentary glomeruli were not found. Daković-Bjelaković M et al [10] described 4 stages of glomerular development, 1) vesicular, 2) comma-shaped (or lipped) and S-shaped, 3) developing capillary loop, and 4) maturing glomerulus. Mishra S et al [6] observed that, at 14th week of gestation, kidney was in a lobulated form showing few differentiated lobules. These lobules showed C-shaped and S-shaped developing tubules and presence of a few developing glomeruli. At 16 weeks of gestation, juxta-medullary glomeruli were larger in size while the peripheral glomeruli smaller. At 22nd week of gestation, the glomeruli were well formed. Tank KC et al [7] observed that, at 12 weeks, the immature developing glomeruli were more in number. At 22 weeks, the number of glomeruli increased. Mature glomeruli were seen in the deeper part of the cortex and were numerically more as compared to the developing glomeruli seen in superficial part of the cortex. At 36 weeks, the mature glomeruli with lobulated capillaries were located just beneath the capsule. Syed SA et al [8] described 7 stages of developing glomeruli, similar to that of present study. They found that at 14th week, the cortex showed more number of developing glomeruli as compared to the mature forms. The immature glomeruli were seen in the superficial part of the cortex while the mature ones with lobulated capillaries in the deeper part of the cortex. Patil S et al [9] found that, at 16th week of gestation, developing renal corpuscles were dispersed within the parenchyma and showed 5 different developmental stages, deep to the nephrogenic zone. More developed stages of renal corpuscles were present in the deeper part of the cortex, while the rudimentary ones in the superficial part. At 31 weeks, the superficial renal corpuscles were well developed.

f) Tubules in the cortex

In the present study, at 13th week of gestation, the developing tubules could not be differentiated into proximal or distal convoluted tubule. PCT and DCT, with their characteristic staining pattern, were identified at 16th week of gestation. From 16th week onwards, they were constantly seen and were better differentiated and identified in the deeper part of the cortex. Mishra S et al [6] quoted that at 22 weeks, at higher magnification, two types of tubules with different staining patterns were observed. One was deeply eosinophilic with small lumen while the other deeply basophilic. According to Tank KC et al [7], at 14th week of gestation, the developing tubules could not be differentiated into proximal or distal convoluted tubules. At 17 weeks, the proximal and distal convoluted tubules could be identified at some places and were better differentiated in the deeper part of the cortex. At 22 weeks, the PCT and DCT were easily identified at higher magnification. Syed SA et al [8] stated that, at 20 weeks, at some places the proximal convoluted tubules and distal convoluted tubules with their characteristic staining pattern were for the first time identified. At 24 weeks, more number of proximal and distal convoluted tubules were identified with their characteristic staining pattern. Patil S et al [9] quoted that, at 16th week stage, the tubules could not be differentiated into proximal or distal convoluted tubules. At 18th week, few tubules could be identified as proximal or distal convoluted tubules. From 23rd week onwards, increased number of PCT and DCT could be indentified in the deeper part of the cortex.

g) JG apparatus

At 16th week, the juxta-glomerular apparatus (JG) was observed. At 18th week, it was seen more distinctly than the previous stage and was better differentiated in the later weeks.

No mention could be found regarding the development of JG apparatus in the earlier available studies.

2) Masson's Trichrome staining

In the present study, we found that, at 13th week, the mesenchymal connective tissue stained green and was abundant. The basement membrane of lining epithelium of parietal layer of Bowman's capsule stained green or blue, depending upon the counter stain used, while the glomeruli stained faint red, because of less vascularity. At 16th week, mesenchymal connective tissue stained blue and was reduced in amount than the previous stage. The glomeruli stained deeply with red colour, indicating its increased vascularity. In the subsequent weeks, mesenchymal connective tissue gradually reduced in cortex while the glomeruli maintaining its deep red colour due to increased vascularity.

3) PAS staining

In the present study, we observed that, at 13th week, the basement membranes of lining epithelium of parietal and visceral layers of Bowman's capsule stained faint magenta in colour while at 18th week, the same were found to be stained deep magenta in colour indicating its better differentiation. No mention could be found regarding the Masson's Trichrome and PAS staining techniques being employed to the histological sections of the developing kidney among the earlier available studies.

Summary and Conclusion

1)Lobulations were seen histologically at 13th week in the present study. At 16th week, initiation of the fusion of lobes was appreciated.

2)The nephrogenic zone was seen up to 32 weeks while it was totally absent at 36 week. Thus it can be concluded that from 36 weeks onwards, there only occurs maturation

of the existing renal corpuscles without the formation of any new corpuscle.
3) The development of glomeruli showed various stages i.e. from vesicular to mature form. The primitive forms of the glomeruli were seen in the superficial part of the cortex while the most mature glomeruli were seen in the deeper part of the cortex, close to medulla, thereby indicating the direction of formation of new glomeruli and their maturation i.e. from superficial to deep.
4) Bowman's capsule became well differentiated with increase in the gestational age.
5) Vascularity of glomeruli increased with increase in the gestational age, thereby moving towards functional maturity of the kidney.
6) The proximal and distal convoluted tubules were identified in the cortex from 16th week onwards.
7) Differentiation between cortex and medulla was seen from 16-18 weeks onwards.
8) Overall vascularity of the cortex also increased with increase in the gestational age.
9) Connective tissue of cortex decreased with increase in the gestational age.

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