Shimane J. Med. Sci. Vol. 2, pp. 103—114, 1978

Developmental Anatomy and Measurements of the Male Urethra and Related Organs in Human Fetuses

(human fetal urethra/measurements/urethral stenosis)

OSAMU TANAKA and YUKIHIRO INOMATA

Department of Anatomy, Shimane Medical University, Izumo 693, Japan

(Received December 22, 1978)

Two hundred and ninety-eight externally normal human male fetuses in Crown-Rump Length (CRL) from 50 to 345mm (10th–36th week of gestation) were examined by dissection for measurements of the urethra, bladder, prostate gland, and cavernous tissues. The urethral passage was examined by infusion of methylene blue dye, and the state of obstruction was observed by dissection.

It was found that the percent increases in the proximal part to the verumontanum were smaller in relation to CRL than in the distal part. Also in the penile urethra the percent of elongation was smaller than in the fixed portion of the urethra. The bladder was contracted in many specimens, but dilated bladders were not always accompanied by urethral obstruction. In contracted bladders, the muscular layer of the anterior wall was thinner than the posterior wall in all specimens. The prostate gland had rapidly grown in cross diameter in the fetuses of CRL 190mm (6th month) and over.

Three fetuses had an urethral obstruction. The urethral passage was obstructed in 22 cases due to meatal atresia of the glans.

These data provide a standard of measurements for pathologists and clinicians and should assist in making an accurate diagnosis in pediatric urology.

The evaluation of pathologic changes in an organ, particularly those occurring early in life, is dependent upon a thorough understanding of normal development. Reliable information on human fetal development of the lower urinary tract, is scanty. In relation to the normal development of the male urethra in human fetuses, there are few descriptive reports such as Johnson's (1). Only small number of fetuses have been studied. There have not been standards regarding normal or abnormal development of the male urethra.

It is necessary to study in detail development of the middle and the lower urinary tracts and related organs in human male fetuses. Since fetal material was available from the Human Embryo Center for Teratological Studies, Faculty of Medicine, Kyoto University, we attempted to elucidate unknown factors.

According to Ambrose (2), atresia and stenosis of the urethra are more common in infancy in males. From 300 cases of fetal ascites in the literature Dockray (3) isolated seven in whom ascites was identified as due to leakage of urine as a result of hydronephrosis caused by obstruction in or below the bladder. We, therefore, examined the passage of fetal urethra in order to observe variations in urethral development in cases of obstruction.

Our objective was to establish standards for measurements and provide data on normal urethral development in human male fetuses.

MATERIALS AND METHODS

The materials for the present study were two hundred and ninety-eight externally normal human male fetuses ranging from 50 to 345mm in Crown-Rump Length (CRL). Their approximate gestation age ranged from the 10th to 36th week, as determined by clinical data and the degree of development of outer anatomical characteristics. In early fetuses with externally undetermined sex, the gonads were examined by dissection. The distribution of fetuses by age and size is shown in Table 1. The fetuses had been fixed in

TABLE I. *Specimens*

CRL*(mm)	Approximate age**(week)	No. of specimens	CRL*(mm)	Approximate age**(week)	No. of specimens
50– 69	10–12	6	210–229	23–24	36
70– 89	12–13	7	230–249	24–26	23
90–109	13–14	7	250–269	27–28	18
110–129	14–15	10	270–289	29–30	9
130–149	16–17	38	290–309	31–32	5
150–169	17–18	50	310–329	32–34	4
170–189	19–20	44	330–349	35–36	4
190–209	21–22	37		Total	298

* Crown-Rump length.
** Fertilization.

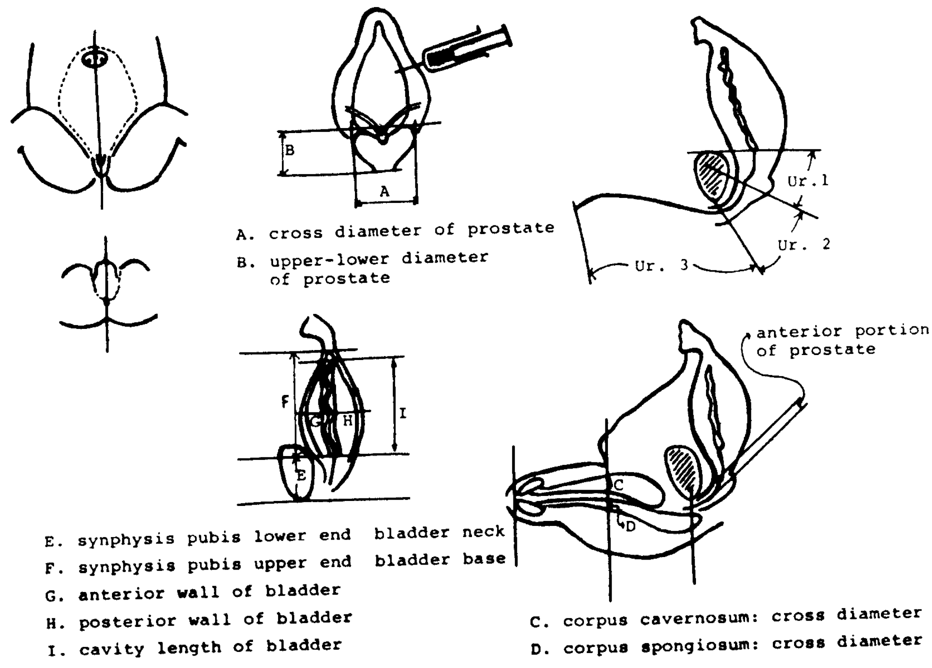

Fig. 1. Procedures of dissection for observation in human fetuses.

10% formalin, generally for not more than one day after death. The fetuses at the CRL and over 150mm were fixed after opening the head and abdomen. All specimens were partially skinned and autopsied at the lower region of abdomen. The procedure of dissection for observation is shown in Fig. 1. The skin was incised along the dotted line as indicated in Fig. 1. The urinary tract, prostate gland and external genital organs were excised, *enbloc.* The cross and the lower-upper diameter were measured on the dorsal surface of the prostate gland. Methylene blue solution was injected through the bladder, as the marker for median dissection. The excised bloc was divided into halves by a median line incision. On the cutting surface, the length of the urethra was measured using slide calipers. The length of the urethra was separated into three portions as indicated in Fig. 1. In 173 of 298 specimens, where the bladders were not dilated by formalin solution, we measured the maximal longitudinal length of the bladder cavity, and the maximal thickness of the anterior and posterior wall of the bladder. The position of the bladder was described by two lengths as indicated in Fig. 1.

If the methylene blue solution injected through the bladder was not projected at the penile tip, the urethra was regarded as obstructed. In this case, the quality of the obstruction was anatomically examined in detail. All measurements in the present study were made using slide calipers.

RESULTS AND DISCUSSION

Measurements and observations are summarized in Figs. 2—7 (reference to Figs. 8-12) and Table 2. Characteristic findings are as follows :

Length of the Male Urethra

The male urethra traverses first the prostate gland, then the urogenital diaphragm, and then the entire length of the corpus cavernosum penis (4). Anatomically, for descriptive purposes it has been separated into three portions : prostatic, membranous, and cavernosus (5). Embryologically, the male urethra is composed of two portions. The upper prostatic urethra, above the level of the colliculus seminalis (verumontanum) is derived from the vesicular portion of the primitive cloaca. Below this level, the lower half of the prostatic urethra and the membranous urethra are derived from the pars pelvina of the urogenital sinus (1). The penile urethra is derived from the pars phallica of the sinus and will be described together with the penis.

The relation between the CRL (Crown-Rump Length in fetus) and the total length of the urethra is shown in Fig. 2. The urethra grows longer in proportion to the increase of the CRL. The pattern of growth is rectiliner. Development of penile length occurs in three stages with the CRL (Fig. 2). At the first stage, the penile length of the fetuses ranging from 50 to 100mm in CRL is about 3mm. At the second stage, the penile length of the fetuses ranging from 100 to 300mm in CRL, thus growing gradually longer as compared with the total length of the urethra. In this stage, the pattern of growth is rectiliner. At the third stage, the penile length of the fetuses is

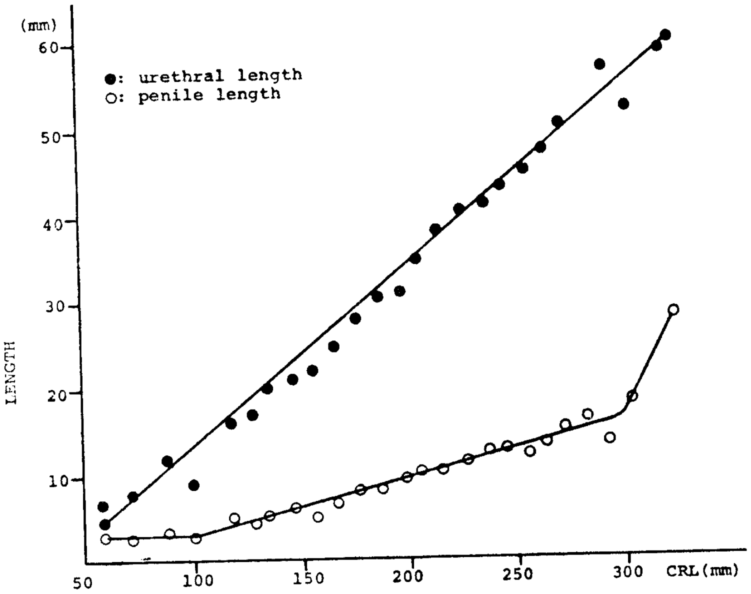

Fig. 2. Relation between CRL and length of the urethra and the penile urethra in fetuses.

300mm in CRL and grows rapidly longer. A this stage, our findings agree with those of Feldman (6).

Next, the urethral length is separated into three portions (see Fig. 1) : (Ur 1) the length from the internal urethral orifice (IUO) to verumontanum, (Ur 2) the length from verumontanum to membranous urethra (MU), (Ur 3) the length from MU to external urethral orifice (EUO). The relation between the CRL and the length of each portion of the urethra is shown in Fig. 3.

The length from MU to EUO grows more rapidly than does the length from IUO to verumontanum and from verumontanum to MU. The growing pattern of IUO to verumontanum is quite similar to that of the length from

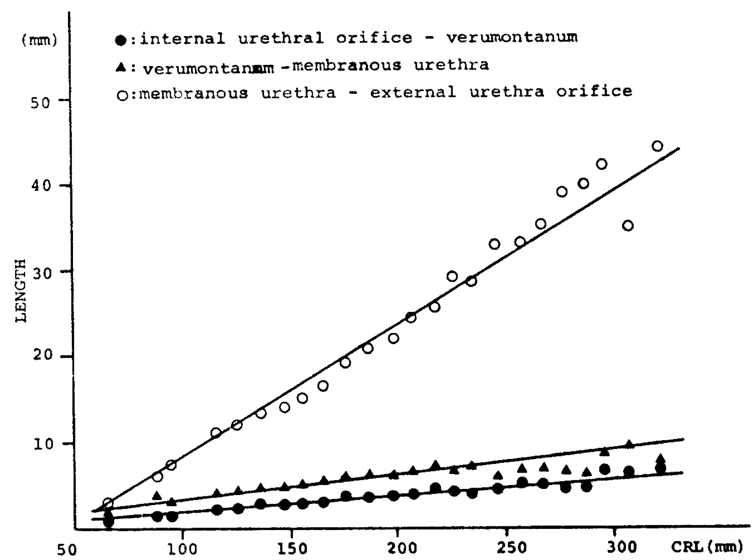

Fig. 3. Length of each portion of the urethra in fetuses.

verumontanum to MU.

According to Hosoya who worked with cytograms, the length of the posterior urethra in the male is 0.255cm during the 4th fetal month (ca. 105mm in CRL), but grows to 2.09cm during the 10th month, that is an eight fold increase (7). These data differ somewhat from the findings in the present study as shown in Fig. 3. The length of the urethra is 0.455cm in the male during the 4th fetal month but extends to 4.52cm during the 10th month, that is a tenfold increase.

Position of the Urinary Bladder and Width of the Bladder Wall

The development of the bladder is closely connected with that of the prostatic portion of the urethra of a human male fetus. The position of the bladder as related to the symphysis pubica is shown in Fig.4. On the basic

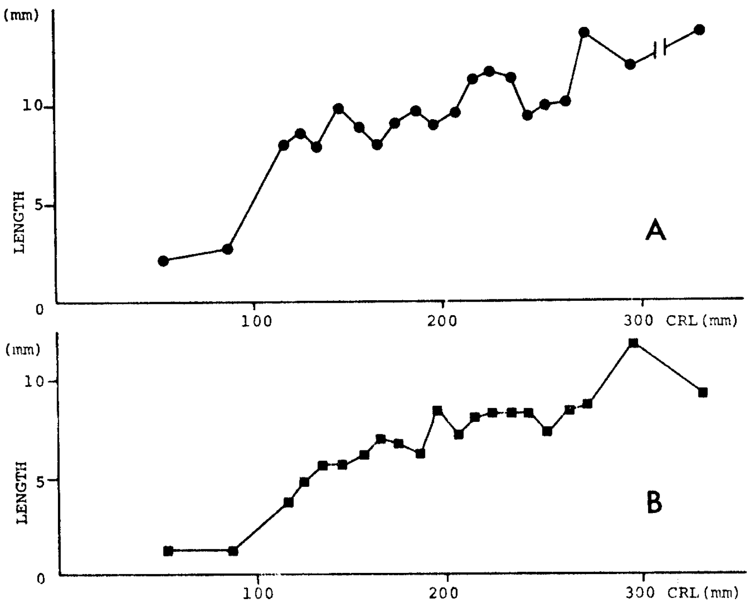

Fig. 4. Position of the bladder in relation to the synphysis pubica in fetuses.

position of the symphysis pubica, the bladder was measured as follows (see Fig.1) : (a) distance between lower end of the symphysis pubica and neck of the bladder (E in Fig. 1), and (b) distance between upper end of the sypmhysis pubica and base of the bladder (F). The distance between upper end of the sypmhysis pubica and base of the bladder was rapidly lengthened at the approximate 100 mm in CRL as compared with the distance between lower end of the symphysis pubica and neck of the bladder at the same stage. It seems that the bladder cavity extends in a longitudinal direction at this stage. According to findings on the cytogram (7), the pelvis and bladder grow upward during the two periods, namely, between 4—6th fetal months (ca. 105—195mm in CRL) and 9—10th months (ca. 300—350mm in CRL). The above mentioned data differ somewhat from the findings of the present study, as seen in Fig. 4. The development of the pelvis is a necessary factor in differentiation in the bladder, and careful observations were made. The bladder at the trigonal region has almost the same circumference as it has over the rest of the area, being at 50mm in CRL stage, a tubular structure which narrows down gradually as it approaches its orifice and nowhere is there a sharply outlined portion which will later become the vesical orifice. The prostatic portion of this tubular structure is marked only by changes in shape (8). These findings are similar to anatomical observations in the present study.

The relation between the CRL and the width of anterior and posterior wall of the bladder is shown in Fig. 5. We replaced the curve line of the

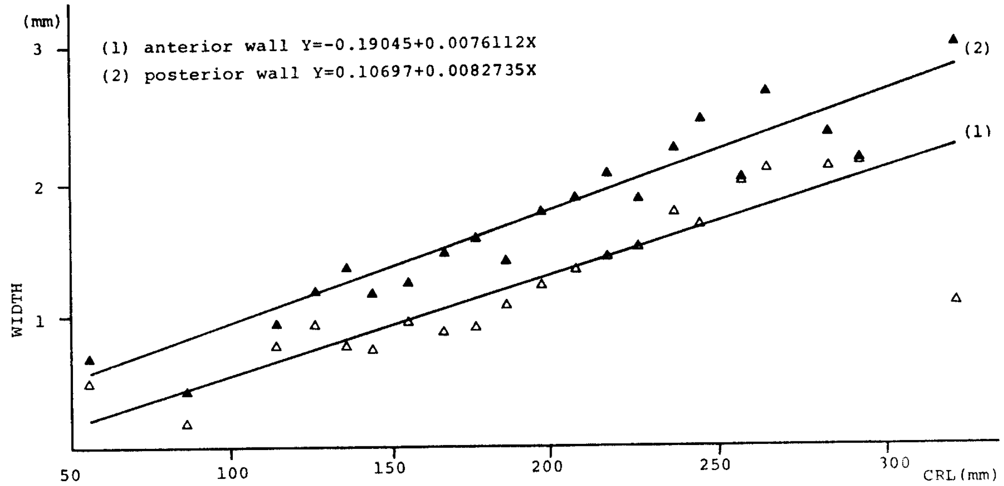

Fig. 5. Width of the bladder wall in human fetuses.

development of the bladder wall with a straight line. The outcome is that the width of the anterior and the posterior of the bladder wall in relation to the CRL are formularized, respectively, as follows : Y (width of each of the bladder wall)$=-0.19045+0.0076112X$ (X: CRL), and $Y=0.10697+0.0082735X$. The pattern of growth of the anterior wall of the bladder is quite similar to the posterior wall. In fetuses ranging from 80 to 210mm in CRL, the upper borders of these bladders are about twice as thick as the bladder wall and are more compactly arranged. Also, lower down, the trigone is less thick and the middle is not so thick as the bladder wall proper. These findings parallel those of the fetus of 190mm in CRL which was reported by Lowsley (8). In a fetus of twenty-two weeks' development (ca. 165mm in CRL), the relation between the size of the trigone and its underlying bladder wall to that of the remainder of the wall of this viscus has changed, for this part of the wall has not enlarged as rapidly as has that of others.

In contracted bladders, the muscular layer of the anterior wall was thinner than the posterior wall, in all specimens. At 280mm in CRL and over, the muscles of the bladder wall were found to increase still further in size, at 345mm in CRL the sphincter is very thick in its posterior quadrant, and shows its greatest dimension at the upper margin.

The ureters in fetuses smaller than 75mm in CRL commonly enter the bladder on the dorsal side in a perpendicular direction, but at 90mm have acquired an oblique course. According to Wesson (9), in a fetus at 80mm in CRL there was an evident oblique course at the entrance of the ureters.

Development of the Size of the Prostate Gland

The relation between the fetal month and the size and shape of the prostate gland is shown in Fig. 6. In the 6th month fetus, the breadth of the prostate gland grows rapidly longer than does the longitudinal measurement.

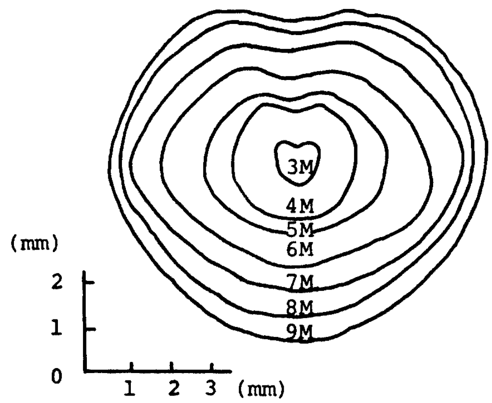

Fig. 6. Development of the prostate gland in fetuses.
M : month of gestation.

The longitudinal measurement of the prostate gland increases in the ventral direction after the 7th fetal month. According to Potter and Craig (11),the prostate is a globular mass almost 1 cm in diameter at birth. The approximate means of the diameter of the prostate found in the present study are as follows : 3M (M : fetal month). 1.0mm ; 4M, 2.7mm ; 5M, 3.4mm ; 6M, 4.9mm ; 7M, 6.0mm ; 8M, 7.2mm ; 9M, 8.1mm.

Embryological studies of the prostate gland in human fetuses have been reported by Lowsley (8, 10), Lowsley and Kirwin (12), Kawabata (13) and Arey (4). However, the data did not include measurements of the prostate gland at fetal stage.

Cross Diameter of the Corpus Cavernosum and the Corpus Spongiosum

The relation between the CRL and cross diameter of the corpus cavernosum and the corpus spongiosum is shown in Fig. 7. Both diameters grow longer gradually in fetuses of 240mm in CRL, but rapidly in fetuses of 250mm in CRL and over.

Urethral Obstruction

There were three fetuses with urethral obstruction and the details are shown in Table II. In such cases, the urethra and bladder were not so dilated as commonly considered in the affected newborn (14).

In 22 cases, the urethral passage was obstructed due to meatal stenosis of the glans. It is not always clear whether meatal stenosis is congenital or the result of an inflammatory process (15). Campbell (16) considered that congenital stenosis of the meatus is a common form of urethral obstruction, particularly in males. In our 22 cases, all had a congenital stenosis as deter–

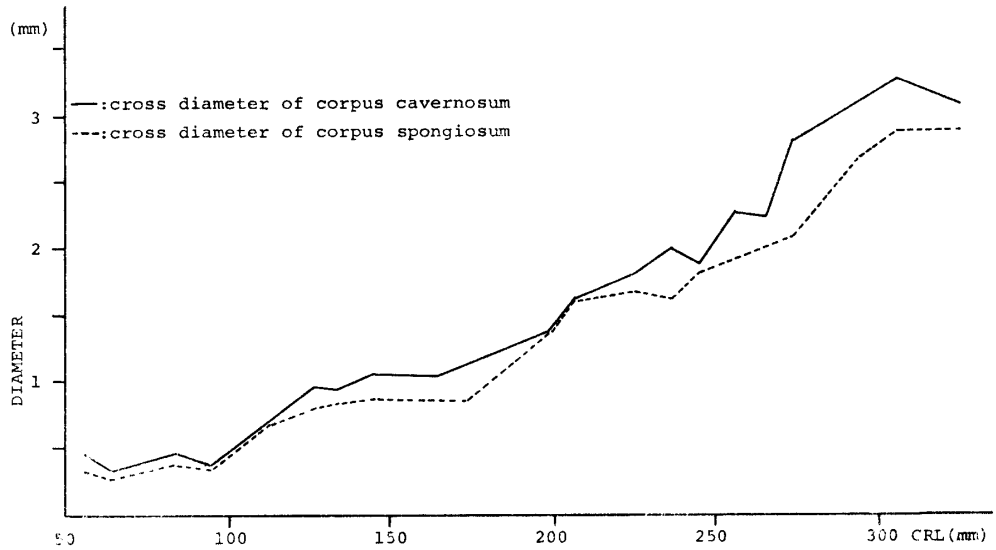

Fig. 7. Cross diameter of corpus cavernosum and spongiosum in fetuses.

TABLE II. *Cases of Urethral Obstruction*

No.	*CRL (mm)	Position of obstruction	Urethra	Bladder
F 1421	137	Penile tip	Not dilated Not short	Slightly dilated trabeculation —
36182	182	Internal urethral orifice	Not dilated Not short	Dilated trabeculation —
F 243	183	In glans penis (1.5mm internal from penile tip)	Not dilated Short	Prominently dilated trabeculation —

* CRL : Crown-Rump length.

mined histologically.

The most distal portion of the urethra is formed during the 4th month, when ectodermal cells from the tip of the glans penetrate inward and form a short epithelial cord extending toward the lumen of the urethra. This cord later obtains a lumen, thus forming the definitive external urethral meatus at the tip of the glans (17).

It seems, therefore, that the meatal stenosis of the glans occurred at these stages (18). According to Leadbetler (19), the congenital urethral stricture may be located at single or multiple positions anywhere in the urethra and is probably due to embryonic narrowing of the channel or, in atresia, failure of tube formation. However, most of our fetuses with meatal stenosis had a single position.

The etiology of the urethral stenosis in males has been described by Lowsley (20), Young (21), Tringoglou and Dickson (22), and Small (23).

Regarding measurements, marked changes in size can frequently be seen in a fetus which has been in formalin for some time. According to Schultz (24), the CRL decreases during 9 months of preservation on an average of 2.5% in human fetuses. The greatest and most rapid change in these measurements occurs at the beginning of preservation.

The absolute size and the condition of the fetuses have no apparent influence on the relative amount of change in the above measurements.

In conclusion, the present study has provided approximate standards of measurements of the male urethra, bladder, prostate gland and cavernous tissues in human fetuses. The significance of such data is that it will provide pathologists and clinicians with a standard from which to make a diagnosis etc.

REFERENCES

1) Johnson, F. P. (1920) The later development of the urethra in the male. *J. Urol.* **4**, 447–502
2) Ambrose, S. S. (1972) The male reproductive tract. In : Embryology for Surgeons (Gray, A. B., et al., eds.) pp. 595–631, W. B. Saunders, Philadelphia
3) Dockray, K. T. (1970) The perirenal P sign. *Am. J. Dis. Child.* **119**, 170–182
4) Arey, L. B. (1974) The external genitalia. In : Developmental Anatomy. pp. 335–341, W. B. Saunders, Philadelphia
5) Anson, B. J. (1966) Male reproductive organs. In : Morris' Human Anatomy. pp. 1435–1507, McGraw-Hill, New York
6) Feldman, K. W. (1975) Fetal phalic growth and penile standards for newborn male infants. *J. Pediatr.* **86**, 395–398
7) Hosoya, K. (1961) Urological studies on Japanese fetuses : Morphologic development of the urinary bladder in the light of cystograms of Japanese fetuses. *Jpn. J. Urol.* **52**, 121–158 (Abs. in English)
8) Lowsley, O. S. (1935) The development of the human prostate gland with reference to the development of other structures at the neck of the urinary bladder. *Am. J. Anat.* **13**, 299–349
9) Wesson, M. B. (1920) Anatomical, embryological and physiological studies of trigone and neck of bladder. *J. Urol.* **4**, 279–288
10) Lowsley, O. S. (1930) Embryology, anatomy and surgery of the prostate gland. *Am. J. Surg.* **8**, 526–539
11) Potter, E. L. and Craig, J. M. (1975) Urinary bladder and urethra. In : Pathology of the Fetus and Infant. pp. 469–475, Year Book, Chicago
12) Lowsley, O. S. and Kirwin, T. J. (1956) Embryology, anatomy, anomalies and physiology of the prostate gland. In : Clinical Urology. pp. 372–381, Wilkins, Baltimore
13) Kawabata, T. (1968) Embryological studies on the prostate in Japanese fetuses. *Tokyo Ikada'gaku Zasshi* **26**, 931–970 (Abs. in English)
14) Warkany, J. (1975) Malformation of the urogenital system. In : Congenital Malformations. pp. 1080–1084, Year Book, Chicago
15) Gyllensten, L. (1949) Contributions to embryology of the urinary bladder : development of definitive relations between openings of Wolffian ducts and ureters. *Acta Anat.* **7**, 305–326
16) Campbell, M. (1951) Stenosis of the urethral meatus. In : Clinical Pediatric Urology. pp. 482–495, W. B. Saunders, Philadelphia
17) Langman, J. (1975) External genitalia in the male. In : Medical Embryology. pp. 186–187, Wilkins, Baltimore
18) Willis, R. A. (1962) Malformations causing urinary obstruction. In : The Borderland of Embryology and Pathology. pp. 199–200, Butterworths, London
19) Leadbetler, G. W. (1963) The etiology, symptoms, and treatment of urethral strictures in male children. *Pediatrics* **31**, 80–86
20) Lowsley, O. S. (1914) Congenital malformation of the posterior urethra. *Ann. Surg.* **60**, 733–741
21) Young, D. N. (1970) Embryology of the urethral valves. *J. Urol. Nephrol.* **76**, 200–207

22) Trigoglou, S. and Dickson, F. (1972) Lower urinary obstruction in infancy. A review of lesions and symptoms in 165 cases. *Arch. Dis. Child.* **47**, 215–217
23) Small, M. P. (1978) Anterior urethral valves. *Urology* **11**, 262–265
24) Schultz, A. H. (1919) Changes in fetuses due to formalin preservation. *Am. J. Phys. Anthropol.* **2**, 35–41

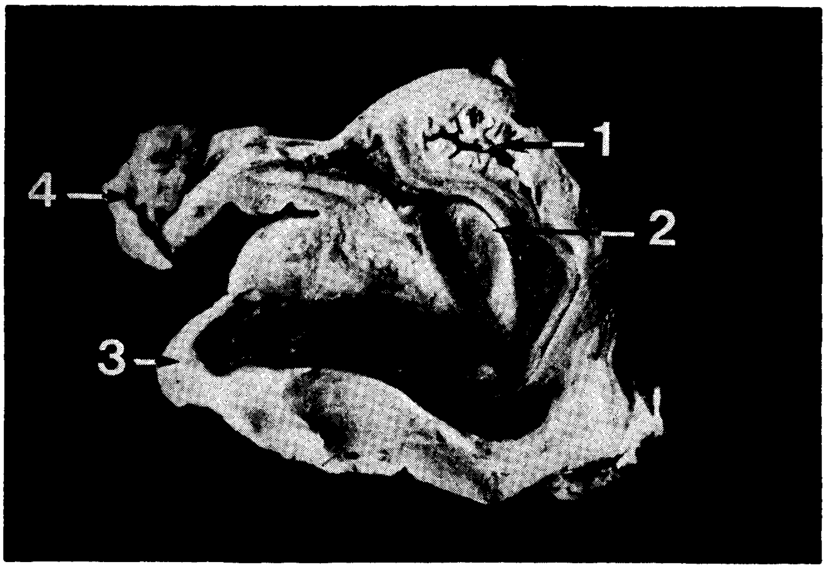

Fig. 8

Fig. 9

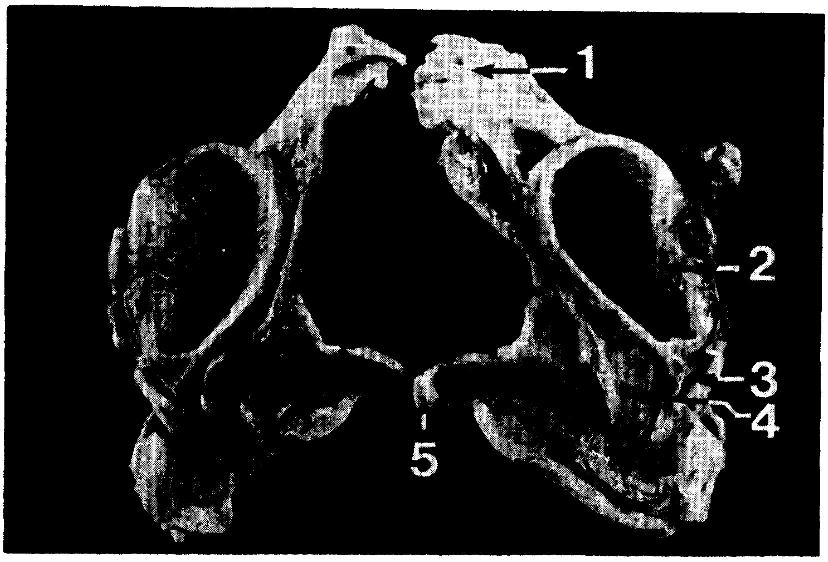

Fig. 10

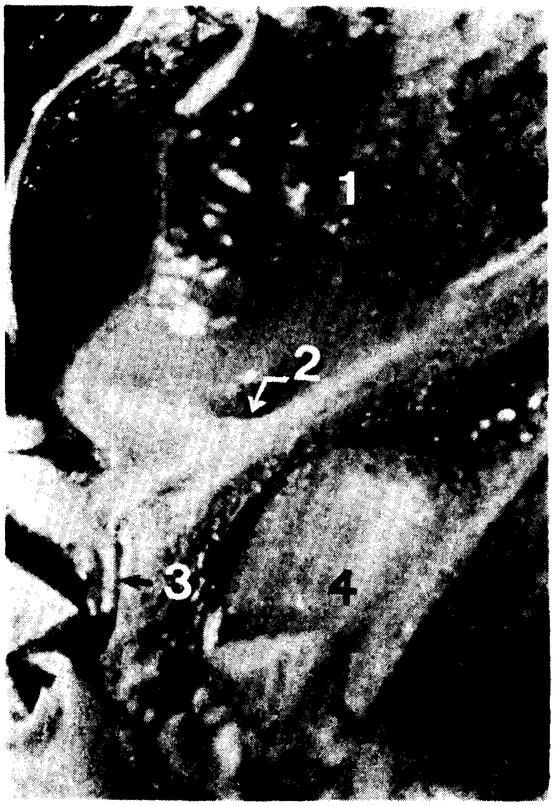

Fig. 11

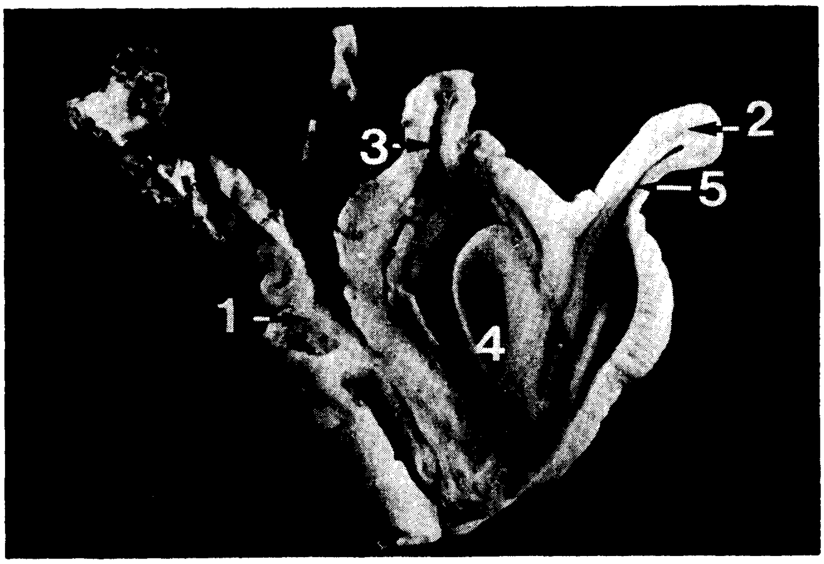

Fig. 12

LEGENDS TO FIGURES

Fig. 8. Normal fetus of 291mm in CRL. (× ⅔)
Course of middle and lower urinary tract on the sagittal median plane. 1. Contracted bladder 2. Cutting surface of pubic bone 3. Penis 4. Umbilical cord

Fig. 9. Normal fetus of 180mm in CRL. (× 2)
Posterior view of prostate (Rectum and connective tissues around the prostate gland are eliminated). 1. Posterior wall of bladder 2. Seminiferous tubule 3. Prostate gland 4. Anus

Fig. 10. Bladder neck obstruction, a fetus of 182mm in CRL. (× ⅔)
Dilated bladder (The block of genitourinary organs is divided into halves on the mid-sagittal plane). 1. Umbilical cord 2. Bladder cavity 3. Seminal vesicle 4. Cutting surface of pubic bone 5. Penis

Fig. 11. Bladder neck obstruction, a fetus of 182mm in CRL. (× 4)
Magnification of the trigonal region of the bladder of the same fetus in Fig. 10 (Internal urethral orifice is obstructed). 1. Bladder cavity 2. Indentation, which should continue to the urethra 3. Prostatic portion of the urethra 4. Cutting surface of the urethra

Fig. 12. Urethral obstruction at the penile tip, a fetus of 137mm in CRL. (× 4/3)
Bladder is slightly dilated while the urethra is not. 1. Rectum 2. Penis 3. Bladder cavity 4. Cutting surface of pubic bone 5. Penile urethra