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Pelvic anatomy

1. Pelvic floor muscles

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Summary

An account is given of the findings of a detailed study of the neonatal and infant pelvis, demonstrating the basic subdivision of the muscles of the pelvic floor into two groups. This subdivision has a functional application. The posterior group of obturator muscles perform a simple diaphragmatic role, while the pubovisceral muscles, in addition to supporting the pelvic viscera, can by active contraction draw them upwards and forwards.

Technical note

This account of the anatomy of the muscles of the pelvic floor is based on a study of neonatal and infant pelves. The study was carried out by gross dissection and serial section of 13 pelves isolated by subcutaneous dissection. The serial sections were cut 7–10 μm thick and stained with either haematoxylin and eosin (HE) or phosphotungstic acid and haematoxylin (PTAH).

The paucity of fibrous tissue in the neonate and infant makes identification of muscle groups and individual muscles easier. In this age group also the specimen size was suitable for serial section and mounting on microscope slides.

Introduction

My interest in the normal anatomy of the pelvic floor was aroused by the difficulty in interpreting the pressure changes in the anal canal[1] without a detailed knowledge of the anatomy of the region. Further, it was not possible to describe the changes in the anatomy of the congenital anomalies of the anorectum without a sound knowledge of the normal anatomy. It was also felt that a comprehensive knowledge of the anatomy would facilitate the optimum placing of muscle stimulator electrodes.

Anatomical subdivision of the muscles of the pelvic floor or levator ani

From Vesalius' account[2] of the 'musculi sedem attolentes' it has been appreciated that the pelvic floor or diaphragm[3,4] is made up by a group of muscles. Since this time the levator ani has come under examination by anatomists and surgeons including Meyer[3], Holl[4], Thompson[5], Elliott-Smith[6,7], Gorsch[8,9], Courtney[10], Uhlenhuth[11], and Wilson[12].

Since the detailed accounts of Holl[4] in 1897 and Thompson[5] in 1899, the muscles have been subdivided on comparative anatomical grounds. In this subdivision the pubococcygeus included those muscles arising from the pubes, either directly from the body or indirectly from the superior ramus through their insertion into the arcus tendineus (white line) of the obturator fascia. The iliococcygeus included those fibres arising from the remainder of the arcus, and thus indirectly via the attachment of the obturator fascia to the superior ramus of the ilium, and from the medial aspect of the ischium. Finally, those

fibres arising from the tip and the posterior border of the spine of the ischium were termed the coccygeus or ischiococcygeus.

Though the plane between the iliococcygeus and the coccygeus is a clear one, the separation of the pubococcygeus from the iliococcygeus was based on an imaginary line extending up from the anterior edge of the ischial tuberosity to the junction of the superior ramus of the pubis with that of the ilium. The point where this line crossed the arcus tendineus represented the division[4,5], which necessitated the grouping of some of the fibres arising from the obturator membrane with those arising from the body of the pubis (Fig. 1*a* and *b*, shaded area). More important, it gave a medial attachment of the pubococcygeus to the anterior sacrococcygeal ligament[8]. Later authors[11,12] have described a separate slip lying in the upper plane of the attachment to the arcus which they have grouped with the pubococcygeus to conform to these subdivisions.

Functional and anatomical concept of true diaphragmatic and pubovisceral muscle groups

In dissection of neonatal and infant pelves I have found a clear plane of cleavage between those muscles arising from the body of the pubis and those arising from the arcus tendineus of the obturator fascia. Those arising from the latter have shown an uninterrupted attachment extending across the fascia to the medial aspect of the spine of the ischium. No similar well-defined plane was found between the fibres originating from the arcus tendineus which might indicate a separate group of fibres anteriorly. In this respect my findings are more in accordance with Lartschneider's[13] description of 'portio pubica' and 'portio iliaca'.

On studying the insertion of these muscles a further advantage of this subdivision was noted. The muscles arising from the body of the pubis either inserted directly into, provided a sling for, or inserted into a structure intimately associated with the pelvic viscera. On the other hand the muscles arising from the arcus tendineus formed a continuous sheet which inserted via 3 main laminae into the anterior sacrococcygeal ligament and, through this, to the anterior surface of the bodies of the lower sacral–coccygeal vertebrae and the anal canal only where the tendon blended with the conjoined longitudinal muscle (Fig. 1*a* and *b*). Thus at either end they were predominantly attached to skeletal structures. Behind the obturator muscles the coccygeus, arising from the margins of the spine of the ischium and fanning out to insert into the sacrum and coccyx lateral to the sacral foramina, showed a more direct skeletal attachment. Thus behind there is a diaphragmatic group made up of the muscles arising from the obturator membrane and the coccygeus, their lateral attachment extending forwards, along the arcus tendineus, and reaching the body of the pubis through the attachment of the obturator fascia. The most anterior fibres curve back and down to form an inverted arch with the muscles of the opposite side. The muscle as a whole slopes medially, downwards, and forwards to form a gutter in which the rectum lies.

In front the viscera pass through the space, in front of this arch and behind the pubis. In this space they are supported by the pubovisceral muscles which, extending from the pubis to the individual viscera, fill the lateral spaces and thus perform a secondary diaphragmatic role. The pubovisceral group as a whole arises from a curved origin, convex upwards, from the back of the pubes (Fig. 1*a* and *b*). Posteriorly the origin overlaps, or is overlapped by, the extension of the arcus tendineus to the pubic bone, in front of the obturator canal. It then curves downwards, medially and forwards to reach the pubic

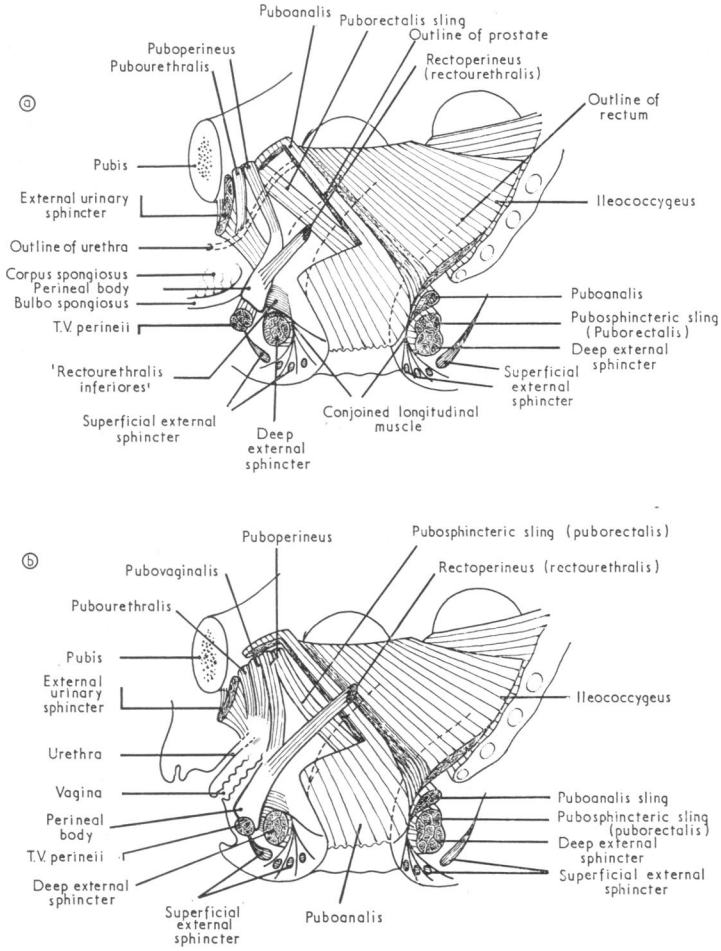

FIG. 1 *Diagrammatic representation of muscles of the pelvic floor and urinary and anal sphincters in infancy: (a) male; (b) female. Dotted lines indicate outlines of rectum, prostate, and urethra. The puboanalis is cut away.*

symphysis.

The pubovisceral muscles at their origin make up two well-defined layers, though Uhlenhuth[11] describes further subdivisions. With the differing pelvic viscera of the male and female, the constituent muscles and their attachments vary. In the male the upper layer constitutes the major component. The fibres arising from the posterior three-quarters of this upper attachment pass back, medially, and down as a broad strap of muscle, the puboanalis. The more anterior of these fibres insert into the circumference of the anal canal[4,6-11] (Fig. 1*a* and *b* and Fig. 2). The more posterior spiral round the anterior border of the 'diaphragmatic' group of muscles to reach their undersurface. Here they decussate with the contralateral muscle, behind the rectum and below the anterior sacrococcygeal ligament, blending anteriorly with the conjoined longitudinal muscle. This portion corresponds with Uhlenhuth's[11] 'semi-tubular' portion of the 'puborectalis'. The attachment of the puboanalis to the anal canal appears to be via a series of musculotendinous slips which lie in two layers[10,11]. The upper slips pass between the longitudinal muscle bundles to insert into the mucocutaneous

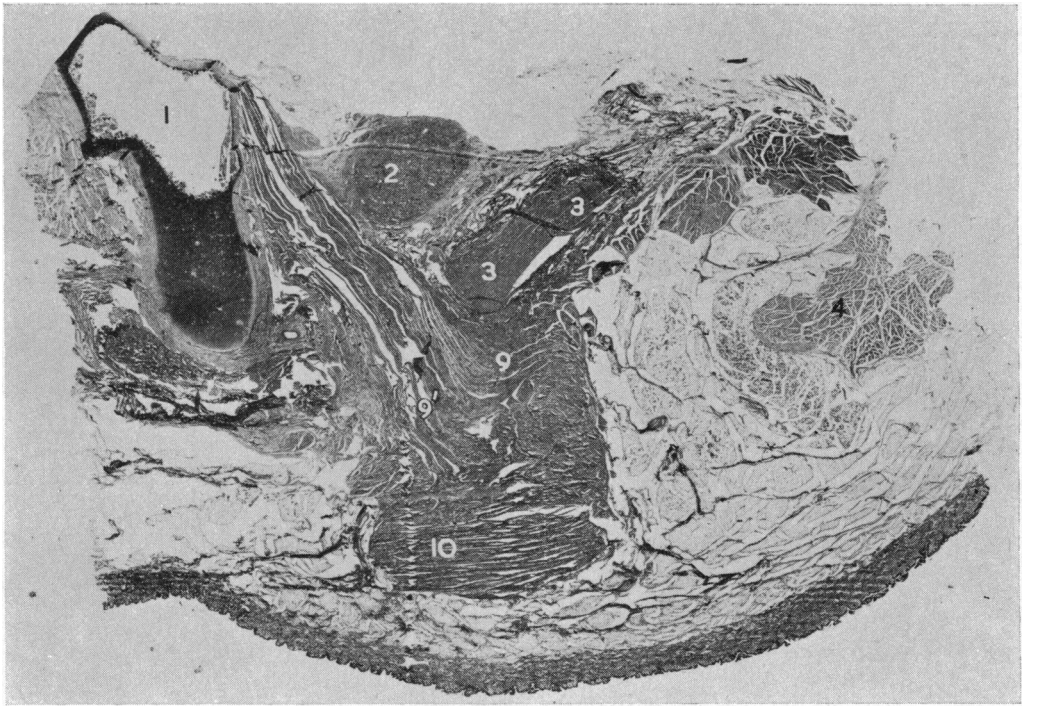

FIG. 2 *Parasagittal section (HE × 3) showing puboanalis fibres passing down to insert into the anal canal and also passing back as sling fibres. (1) pubis; (2) prostate; (3) rectum; (4) coccygeus; (5) iliococcygeus, (9) puboanalis sling, (9') puboanalis passing to insertion into anal canal; (10) deep anal sphincter.*

junction. The slips in the lower layer interdigitate with the smooth muscle bundles and pass down to the perianal skin (Fig. 3).

Two further muscles arise from this line of origin from the pubis. The more anterior passes almost directly down, medially, and back to insert into the posterolateral aspect of the apex of the prostate and the membraneous urethra. This muscle, the pubourethralis (or prostaticus) (Fig. 4), passes behind the upper loops of the sphincter urinae externus, though some of the inferolateral fibres pass as a separate slip outside the sphincter to blend with the bulbospongiosus raphe[11,14]. From an origin behind the pubourethralis a distinct muscle bundle passes back, medially, and down, completing its course in an areolar tunnel, to insert into

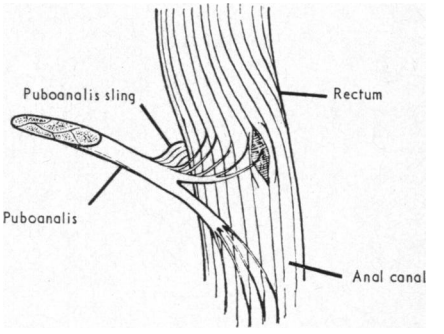

FIG. 3 *Schematic drawing from dissection showing anterolateral view of puboanalis insertion into the anal canal. This shows the musculotendinous slips, in the upper layer passing between bundles of longitudinal smooth muscle of the anal canal to reach submucosa and in the lower to interdigitate with them to form the conjoined longitudinal muscle. The puboanalis sling fibres are seen passing behind the rectum.*

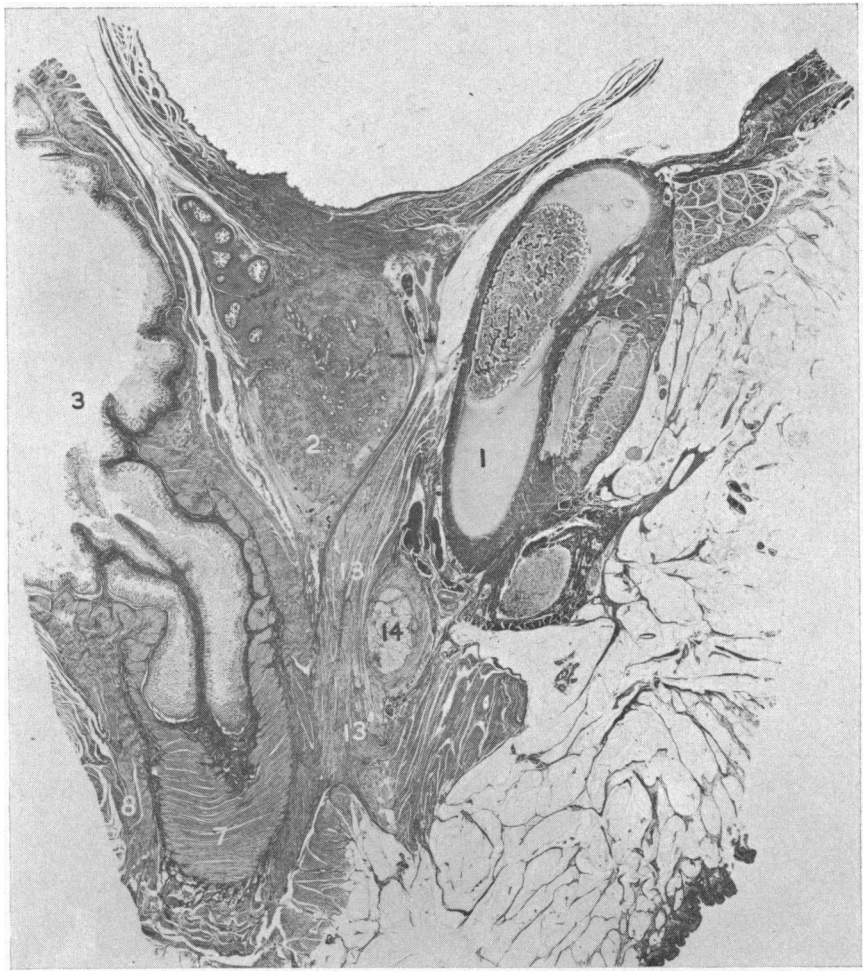

FIG. 4 *Parasagittal section (PTAH × 3) showing pubourethralis passing down to insert into the apex of the prostate and urethra posterolaterally and extending down to the bulbospongiosus raphe. (1) pubis; (2) prostate; (3) rectum; (7) internal anal sphincter; (8) conjoined longitudinal muscle; (13) pubourethralis; (13′) pubourethralis extension to pubospongiosus muscle; (14) paraurethral gland.*

the superolateral angle of the perineal body (Fig. 1*a* and *b* and Fig. 5). This muscle I have called the puboperineus and it is included in the prerectal fibres described by Holl[4], Elliot-Smith[6,7] and Uhlenhuth[11].

The attachments of the muscles of the lower layer extend more medially, reaching the lower part of the symphysis pubis. In the male a distinct straplike muscle (0.2 cm in diameter in our neonatal dissection) arises medially and crosses the inferolateral surface of the pubourethralis, puboperineus, and puboanalis. It crosses these muscles obliquely from above down, separated from them by loose areolar tissue. It completes its course by blending with the posterior third of the deep

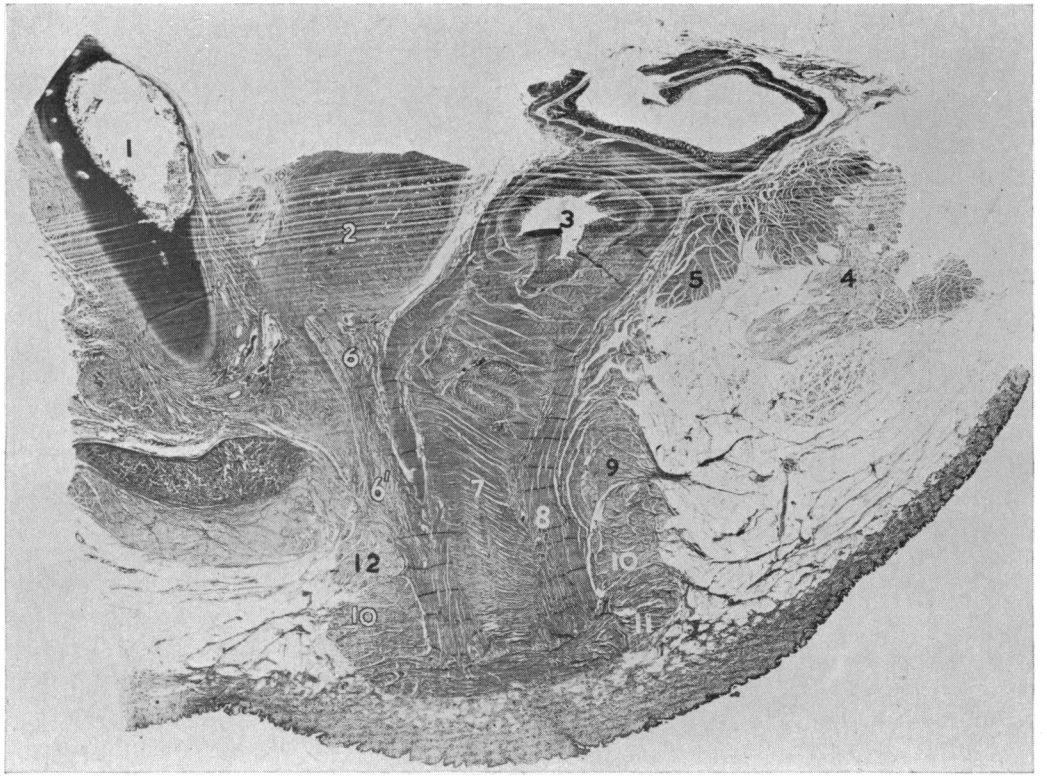

FIG. 5 *Parasagittal section (HE × 3) showing puboperineus passing down to its insertion into the perineal body. (1) pubis; (2) prostate; (3) rectum; (4) pubococcygeus; (5) ileococcygeus; (6) puboperineus; (6') insertion of puboperineus into perineal body; (7) internal anal sphincter; (8) conjoined longitudinal muscle; (9) puboanalis sling; (10) deep anal sphincter; (11) superficial anal sphincter; (12) transverse perineii.*

sphincter ani[8,10] below the puboanalis sling fibres (Fig. 1*a* and *b* and Fig 6). This muscle is described by Gorsch[9] as 'the puborectalis', but Holl[4] and Uhlenhuth[11] group it with the puboanalis as part of their 'puborectalis'. To avoid the confusion of the differing uses of the term 'puborectalis' I will call this muscle the puboanal sphincteric sling because of its close association with the deep anal sphincter.

In the female the pubovisceral group arises, as in the male, from the curved origin from the back of the body of the pubes (Fig. 1*b*) but here the puboanalis makes up the whole of the superior layer at its pubic attachment. The fibres then pass back, medially, and

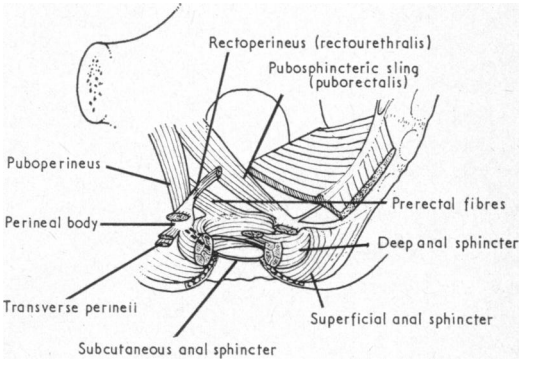

FIG. 6 *Schematic drawing, with muscles arising from obturator membrane and puboanalis cut away, to demonstrate the relationship of puboperineus, prerectal fibres, and pubosphincteric sling to the voluntary anal sphincters.*

down to insert into the circumference of the anal canal, the posterior fibres decussating behind it as the puboanalis sling.

In the lower plane, extending as far medially as the pubic symphysis and arising as a continuous sheet, muscle fibres pass down, back, and medially to insert into the urethra and vagina. A more distinct bundle passes posteriorly between the rectum and vagina to insert into the supralateral angle of the perineal body. Some of these fibres pass pack to blend with the deep anal sphincter (prerectal fibres of Holl[4], Elliot-Smith[6,7], and Uhlenhuth[11]).

The puboanal sphincteric sling arises behind the puboperineal fibres, passing obliquely back and down across the ischiorectal surface of the puboanalis to blend, as in the male, with the deep anal sphincter.

Nerves in relationship to the pelvic floor

There is a considerable concentration of nervous tissue in relation to the upper surface of the pelvic floor and the pelvic viscera. Much, forming into plexuses, is derived from the autonomic system. The levator ani derives its nerve supply from two sources. Firstly, nerves arising from the sacral anterior primary rami crossing the upper surface. Secondly, the pudendal nerve, also arising from the anterior primary rami (S2, 3, and 4, *Gray's Anatomy*, 2nd edition) of the sacral nerves, reaches the ischiorectal fossa by crossing the lateral aspect of the spine of the ischium to supply the muscle by branches below the pelvic floor.

Autonomic nerves My findings correspond with those of Learmonth[15] and Scott[16]. Two plexuses of nerves and ganglia, the pelvic ganglia, arise from the hypogastric plexus, passing downwards and forwards obliquely across the lateral surface of the lower rectum to reach the region of the perineal body and posterior urethra. Through these plexuses distinct bundles can be traced from the anterior primary rami of the third and fourth sacral nerves on either side to reach the posterior urethra (nervi erigentes). These plexuses are closely applied to the rectum, though fibres derived from the hypogastric plexus and lateral roots (nerves of Learmonth) cross the upper surface of the pelvic floor to reach the ureters.

Somatic nerves The somatic nerves of the upper surface of the pelvic floor are quite distinct from the autonomic plexuses and lie closely applied to the muscle below the pelvic fascia (Fig. 7). They appear to have received little detailed study until recently[17,12]. My findings correspond with the variants described by Stelzner[17]. The nerves arise from the anterior primary rami of the third and fourth sacral nerves with an occasional contribution from the fifth. They either continue as separate nerves or form a single trunk. If the former, then one or other nerve may predominate. They pursue a course across the levator ani at the junction of the medial and lateral thirds of the muscle to terminate in the posterior urethra. The portions of the levator ani are supplied by

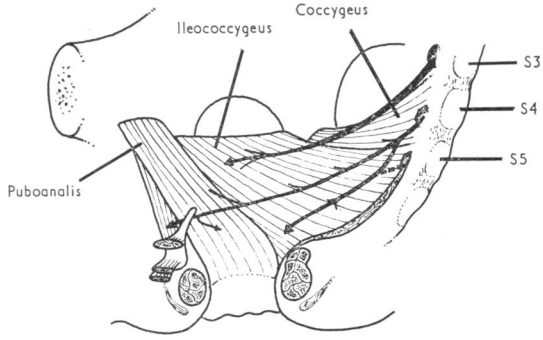

FIG. 7 *Pelvic floor nerves. Schematic drawing showing the course of the pelvic nerves across the levator ani and indicating the lateral muscular branches. Also the medial visceral branches and the continuation extending forwards to the urethra.*

lateral branches but, in addition, two branches pass medially to reach the anal canal just above the attachment to the puboanalis and at the level of the stratified cuboidal cell zone of the anal canal.

Below the pelvic floor two nerves, one arising more posteriorly from the pudendal nerve and the other arising more anteriorly from the perineal nerve, pass down the medial wall of the ischiorectal fossa, supplying the undersurface of the levator ani (pubosphincteric sling portion) to be distributed to the voluntary anal sphincters, transverse perineii, anal canal, and perianal skin.

Application

From this account it will be seen that the subdivisions of the levator ani have a functional application. The posterior group of obturator muscles performs a simple diaphragmatic role. On the other hand the pubovisceral muscles, in addition to supporting the pelvic viscera, can also by active contraction draw these viscera upwards and forwards. The pubourethralis, pubovaginalis, and puboanalis by nature of their insertion in addition tend to draw the urethra, vagina, and upper anal canal open and may contribute to the rapid fall in pressure in the upper anal canal at the commencement of defaecation[1,18] and the initiation of micturition. In this context it is significant that branches of the pelvic floor nerves supply these muscles, the upper anal canal, and the posterior urethra.

On the other hand the sling fibres of the puboanalis, the puboanal sphincteric sling (puborectalis) and the puboperineus, acting through the perineal body, in addition to drawing up the pelvic viscera would also tend to close the urethra, vagina, and anal canal. The close relationship of the pubosphincteric sling to the deep anal sphincter, in structure and in its common nerve supply from the pudendal nerve, makes it particularly suited to this role.

With voluntary arrest of defaecation or micturition contraction of the voluntary sphincters, with the help of these sling muscles, will squeeze back the anal and urethral contents and remove them from contact with the sensitive mucosa of the upper anal canal and posterior urethra, both of which are supplied by branches of the pelvic floor nerves.

It will be seen that to prevent damage to the pelvic plexuses and nervi erigentes in

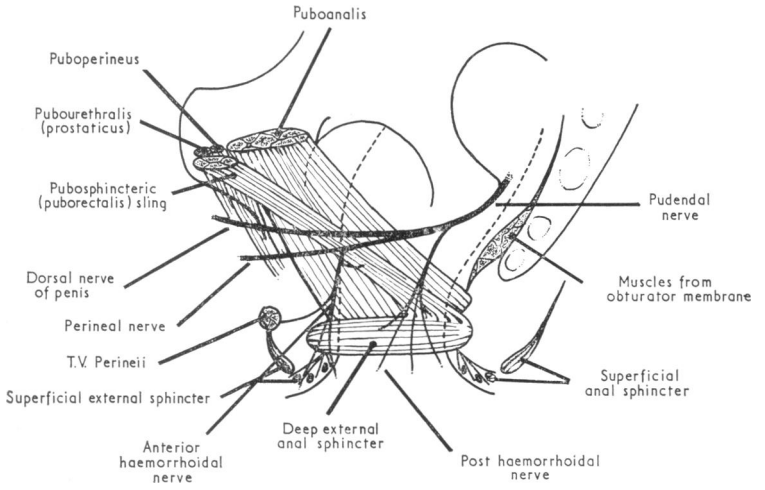

FIG. 8 *Schematic diagram to show the distribution of pudendal nerve below the pelvic floor.*

operations on the rectum and anal canal dissection must be carried out very close to the rectal wall. The nerves to the pelvic floor, on the other hand, lie more laterally and are less liable to be damaged[17]. Below the pelvic floor the nerves to the pelvic floor and sphincters run down in the medial wall of the ischiorectal fossa (Fig. 8) and thus extensive incisions can be made into the ischiorectal fossa, for sepsis and in the buttock-reflecting incision[19], without denervation of the sphincter or loss of perianal sensation[20,21].

It is interesting to note that the pudendal nerve, supplying the pubovisceral sling muscles and voluntary sphincters, has a higher spinal segmental origin (S2, 3, 4) than that of the nerves to the pelvic floor (S3, 4 (5)). The anal and urethral branches, arising predominantly from S4 (5) supply the very sensitive zones of the urethra and anal canal, where the entry of contents is followed by profound sphincter inhibition[1,18]. These facts probaby account for the preservation of tonic sphincter contraction in some cases of neurogenic bladder due to meningomyelocele and sacral agenesis where sensation is lost.

The tendinous layer met with after disarticulation of the coccyx during the posterior, sacral, approach to the pelvic floor and in the abdominoperineal resection of the rectum for carcinoma represents the anterior sacrococcygeal ligament.

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(The second part of this paper will appear in a subsequent issue.)