Descent of the Testis

Second Edition

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Preface

Descent of the testis, or lack thereof, is a subject of great controversy in embryology, endocrinology, and paediatric surgery. For such a common abnormality as undescended testis, it is surprising that there still remain so many unanswered questions, more than 20 years after our first edition (Table 1).

This book aims to present up-to-date evidence from our own and other laboratories of the normal mechanisms of testicular descent (Chaps. 2 and 3), along with a brief description of the evolution of descent and the early history of research into its cause (Chap. 1).

Chapters 4–10 describe the clinical problems of undescended testes and give our own, necessarily biased, opinion of the best ways to diagnose and treat the anomaly. We have not emphasised hormonal treatment, which has been vigorously proposed by others in recent years, for two major reasons. First, current evidence now suggests that direct or indirect stimulation of androgen secretion only causes relaxation of the cremaster muscle in "retractile" testes, but has little effect on truly undescended testes. Second, luteinising hormone-releasing hormone (LHRH) or its long-acting analogues have not been approved for clinical use in Australia, and one of the authors (JMH) has no direct experience of their use. Human chorionic gonadotrophin (hCG) is available, but is not in general use because of lack of efficacy and the need for a significant number of painful injections. Buserelin (LHRH analogue) is in use in some parts of Europe, but its efficacy remains very controversial.

The descriptions of the clinical diagnosis (Chap. 7) and the surgical treatment (Chap. 8) are given in detail, with extensive pictorial support, so as to give the trainee surgeon enough information to be able to learn exactly what we do. We have opted for a detailed description of orchidopexy as it is performed currently. Previous surgical techniques have been omitted deliberately because they were cruel, unnecessary, or caused testicular atrophy. There is now no place for such methods in modern paediatric surgery, where the goal is to perform day-case surgery with minimal pain or discomfort to the hapless infant or child. With this approach, orchidopexy can be performed without any painful injections or unpleasant memories.

Table 1 Questions needing answers about testicular descent

Why does the testis descend?
How does the testis descend?
What causes undescended testes?
What is the best treatment for maldescent?
Does hormone therapy have a role in treatment and/or diagnosis?
Are there any new alternatives to surgical treatment?
When is the optimal time for treatment?
Are "retractile" testes normal or abnormal?
Do retractile/ascending testes need treatment?
What is the cause of infertility and increased malignancy?
Will fertility improve and the risk of cancer diminish with current modes of treatment?

The long-term results of current surgical treatment (Chap. 10) remain unknown, but we are optimistic that surgery in infancy will lead to a significant improvement in fertility and reduced risk of malignancy.

Chapter 11 concludes this short monograph with an attempt to summarise our answers to the list of questions given above. Inevitably, some of our answers will be found wanting in the future, but they will serve as a guide to future advances. Finally, we speculate on the ways that undescended testes may be treated in the future, based on our research into normal mechanisms of descent and the physiology of the testis.

There are many areas of the subject that we have not dealt with extensively; the reader should consult those books that address these areas directly. For a classic description of the human problems, the reader could do no better than read Scorer and Farrington's 1971 treatise [1]: we have attempted unashamedly to emulate its style and approach. During the 1970s and early 1980s, the dominant paradigm was the central role of the hypothalamic-pituitary-gonadal axis which provided the rationale for hormone treatment. Several good multi-authored volumes appeared at that time, with extensive discussion of all endocrine aspects of the problem [2–7]. The role of hormones in treatment was questioned in 1986 by de Muinck Keizer-Schrama and Hazebroek in their joint thesis from Erasmus University, Rotterdam [8].

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1 Evolution of Descent of the Testis and Early History of Research

1.1 Evolution of Testicular Descent

1.1.1 Why Is the Testis Descended at All?

Early vertebrates had intra-abdominal gonads, regardless of sex. With subsequent evolution of sexual differences in mammals and marsupials, the testis has acquired a different position from the ovary, presumably because this different position has conferred some biological advantage. It is not known exactly why evolution has produced descended testes outside the abdominal cavity, although there is little doubt that the scrotum has become a highly specialised, low-temperature environment. Bedford [1] proposed that descent of the testis is a secondary phenomenon accompanying descent of the epididymis. Since early vertebrates, such as fish, probably ejaculated the semen into the environment, spermatozoa may have acquired advantage by being adapted to environmental temperatures below that of the body: the caudal epididymis, which stores spermatozoa, also might benefit from adaptations to cooler temperatures. In animals where the testis is not normally descended into a pendulous scrotum, the caudal epididymis is the most superficial genital organ and hence is maintained at a lower temperature than the internal organs. The testis which produces spermatozoa also may have acquired evolutionary advantage from being at a lower temperature.

Most mammals have acquired numerous sophisticated anatomical and physiological adaptations of the scrotum to keep the epididymis and testis cool (Table 1.1), many of which are present in the human. Because the human testis has inherited major adaptations fitting it to exist at a lower temperature than the body core, any disruption of normal descent would be expected to upset testicular physiology, as is discussed in Chap. 6.

The different anatomical and physiological characteristics found in different species are important for an overall understanding of human testicular descent because they reveal the various phases through which the mechanism has passed. Some of these phases may be concealed by idiosyncratic anatomical features, but the basic mechanism of testicular descent should be present in increasing complexity.

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Table 1.1 The scrotum as a low-temperature environment

Character	Physiological role
Thin, pigmented skin	Heat loss by conduction/radiation
No subcutaneous fat	Heat loss by conduction
Absent hair/fur (e.g. bull/rat)	Heat loss over caudal epididymis
Pampiniform plexus	Countercurrent heat exchange
Cremaster muscle	Controls testicular position in response to external temperature
Dartos muscle	Controls scrotal dependency in response to external temperature
Fat pad in inguinal canal (e.g. rat)	Insulates testis from abdominal cavity
Fat pad between testis and epididymis (rat)	Insulates caudal epididymis from testis
Processus vaginalis closure (primates)	Keeps testis outside abdominal cavity

1.1.2 Which Animals Have Descended Testes?

Descent of the testis from its initial intra-abdominal position on the ventromedial aspect of the urogenital ridge to an external, subcutaneous scrotum occurs only in mammals. Other vertebrates, such as fish and birds (Fig. 1.1), have testes which remain inside the abdomen. Monotremes, such as the platypus and the spiny anteater or echidna (Fig. 1.2), form an intermediate group between mammals and other vertebrates and have high, intra-abdominal testes [2]. By contrast with the platypus and echidna, modern marsupials such as the kangaroo exhibit complete testicular descent to an external scrotum, albeit in the groin rather than the perineum (Fig. 1.3) [3, 4].

Some eutherian mammals have intra-abdominal testes which remain in their original position on the urogenital ridge. These include such widely different animals as the elephant and the rock hyrax (a small African herbivore) [5] (Fig. 1.4). The elephant (Fig. 1.5) and the hyrax appear to have no structure analogous to the gubernaculum. Aquatic mammals (porpoises, dolphins, and whales) have testes which are partially descended within the abdomen [6, 7] (Fig. 1.6a, b). Meek has speculated that aquatic mammals had descended testes during an earlier epoch, but this feature has been lost to a variable extent in subsequent millennia.

In the narwhale (Fig. 1.6c) [7] and the prairie dog [8] (Fig. 1.7), the testes are lateral to the bladder neck, just inside the inguinal region. Hedgehogs, moles, and shrews have testes lying lateral to the bladder; in spring and presumably in response to a surge of androgens, the enlarged testes protrude temporarily into sacs near the base of the tail [9] (Fig. 1.8). Sloths and armadillos have testes between the bladder and rectum [10].

The testes of the chinchilla are just inside the inguinal aperture, but the caudal epididymis protrudes into a thin-walled scrotal diverticulum [11] (Fig. 1.9). Some animals have testes in a subcutaneous pouch which communicates freely with the peritoneum, as is the norm for rats and mice. The southern elephant seal (Mirounga leonina Linnaeus) has two separate inguinal pouches rather than a single scrotum [12].

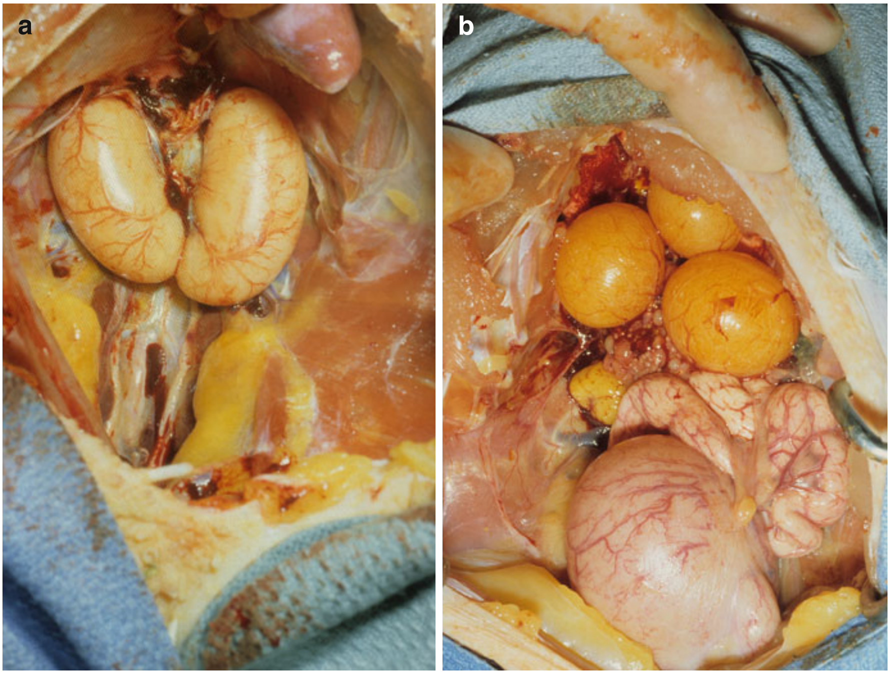

Fig. 1.1 The intra-abdominal gonads of the domestic fowl. (**a**) The large testes are high on the posterior abdominal wall of an adult rooster, near the normal position of kidneys in a mammal. Note that the testes are larger than the heart, shown at the top of the picture. (**b**) The single (*left*) ovary of the hen, showing eggs at various stages of development. The single (*left*) oviduct contains several eggs in transit

Even where a formed scrotum is present, its exact site and degree of development varies widely. The hyaena, for instance, has two posterior shallow scrotal pouches [13], while the kangaroo has a large prepenile scrotum in the groin located directly over the external inguinal rings.

In some mammals, the testicular position relative to the scrotum varies with sexual maturity and season. In the bear, for instance, the testes are scrotal from infancy but are held close to the body, except in the adult during the breeding season, when they are pendulous because of scrotal relaxation. The testes of the rhesus macaque descend prenatally into the scrotum but then reascend to the inguinal canal after birth, only to re-enter the scrotum finally at puberty (Fig. 1.10) [14]. This suggests that the abnormality of 'ascending' testes (that descend into the scrotum at puberty) in the human is normal in the macaque.

As can be seen from this brief summary, only a small number of highly specialised mammals have no testicular descent, e.g. monotremes, hyrax, elephant, and possibly some insectivores. Partial intra-abdominal descent occurs in the Cetacea (porpoises, dolphins, and whales). The testis is inguinal in position in edentates, some insectivores, and some ungulates; these animals probably have ancient origins, despite their highly specialised characteristics. Other animals have a subcutaneous pouch rather than a true scrotum and exhibit periodic or seasonal descent of the testes.

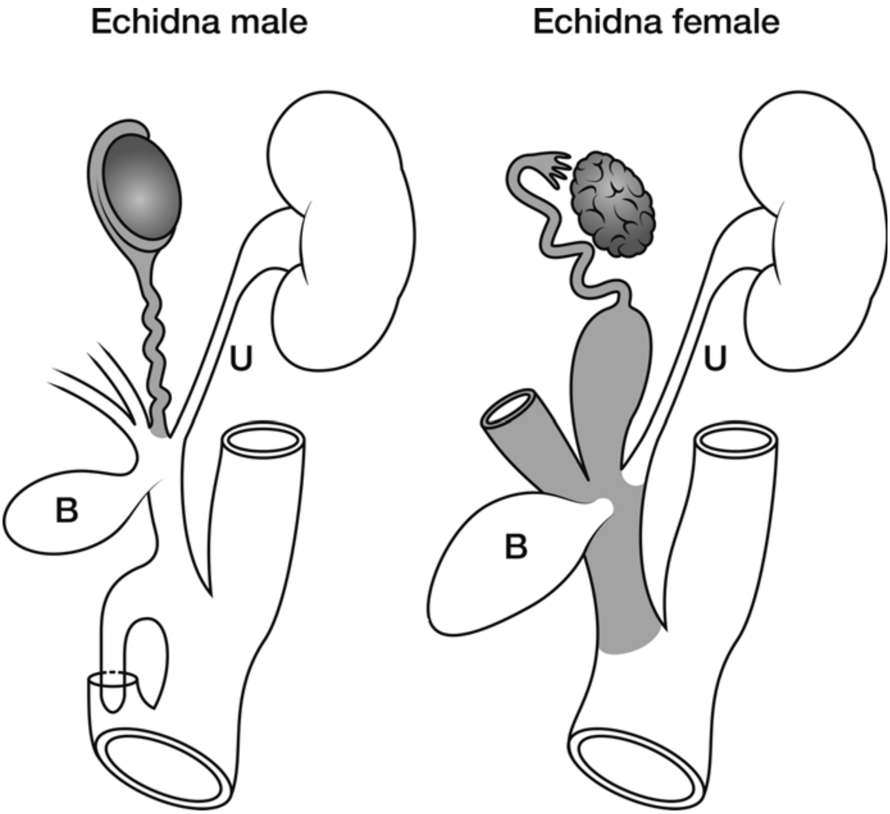

Fig. 1.2 Gonadal position in the monotreme echidna. The testes and ovaries are in a similar intra-abdominal position near the kidneys (Redrawn from Renfree [43]). *B* bladder, *U* ureter

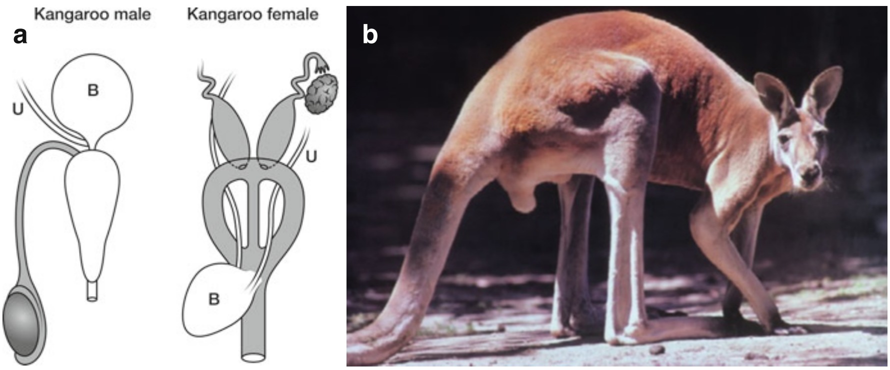

Fig. 1.3 Gonadal position in the marsupial kangaroo. (**a**) In the male, the testis is fully descended into a prepenile scrotum, while in the female, the ovary remains near the kidney. (**b**) The male red kangaroo, showing the descended testes in the scrotum in the inguinal region, in front of the penis