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REVIEW ARTICLE

The intra-abdominal testis: lessons from the past, and ideas for the future

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Abstract The intra-abdominal testis (IAT) has been always an enigma for both diagnosis and treatment. Imaging techniques are known for low sensitivity for localizing the IAT. It has been universally accepted that the gold standard for localizing the IAT is diagnostic laparoscopy. Orchiopexy techniques for IAT are complicated and attended with a higher rate of failure and complication than those for the palpable testis. For the low-lying abdominal testis, a one-stage procedure without interruption of the vessels has a high success rate. The Prentiss maneuver bridges the borders of normal pathway to gain a straighter course to the scrotum. The interruption of the main vascular supply of the testis, depending on collateral circulation, has been used for many years but with questionable effects on the microscopic delicate structure of the testis. Microvascular autotransplantation was intended to avoid this effect, but it is technically demanding and requires special expertise. The principle of traction has been used in the past but was abandoned due to high rate of atrophy. Recently, traction has been revisited with a new approach with very encouraging results. The key to success in any technique for orchiopexy is the complete absence of tension.

Keywords Intra-abdominal testis · Orchiopexy · Cryptorchidism

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Introduction

The etymology of the word testis is referred to Roman's law. The Latin word "testis" means witness, was used in the firmly established legal principle "Testis unus" (one witness), meaning that testimony by any one person in court was to be disregarded unless corroborated by the testimony of at least another. This led to the common judicial practice of producing two witnesses, bribed to testify the same way in cases of lawsuits with ulterior motives. Since such "witnesses" always came in pairs, the meaning was accordingly extended, often in the diminutive (*The American Heritage Dictionary of the English Language*, Fourth Edition.)

Basically, the mammals are known to have internal testes, but large group of mammals that includes humans, have externalized testes. Their testes function best at lower temperature than their core body temperature, so their testes are located outside the body, suspended by the spermatic cord within the scrotum. The testes of the monotremes, armadillos, sloths and elephants remain within the abdomen. There are also some boreotherian mammals with internal testes, such as the rhinoceros [1].

Marine boreotherian mammals, such as whales and dolphins, also have internal testes, but it has recently been shown that they have developed elaborate vascular networks to provide the necessary temperature lowering for optimum function; many boreotherian aquatic mammals have internal testes which are kept cool by special circulatory systems that cool the arterial blood going to the testes by placing the arteries near veins bringing the cooled venous blood from the skin. Recently, a link between internal and external pathways of testes and the mammary line in females has been described in Kangaroo (John Hutson, Personal Communication).

There are several hypotheses why most mammals have external testes which operate best at a temperature that is slightly less than the core body temperature, e.g., that it is stuck with enzymes evolved in a colder temperature due to external testes evolving for different reasons, that the lower temperature of the testes simply is more efficient for sperm production [2].

Cryptorchidism is common in male dogs, occurring at a rate of up to 10 %, dog testes usually descend by 10 days of age and it is considered to be cryptorchidism if they do not descend by the age of 8 weeks.

The stallion and boar are most prone to cryptorchidism among the domesticated species [3].

For unknown reasons, there are some species that do maintain a naturally cryptorchid state for either all or part of the year. Animals such as birds, elephants and their closely related cousins (the hyraxes) do not descend their testicles throughout their lives. These species do not seem to have any trouble breeding, which suggests that their spermatogenesis is able to occur regardless of the internal body temperatures or that they have found other ways of cooling their testicles besides swinging them in the breeze. Interestingly, many rodent and lagomorph species (rabbits, hares, mice, rats, guinea pigs, cavies) have readily mobile retractile testes that are able to move back and forth from the scrotal sac to the abdominal cavity at will. It is thought that some of these species, which have a distinct breeding season, may keep their retractile testicles undescended (infertile) during the off-season and only descend their testicles just prior to and during the mating season, when viable sperm production is required [3].

The first comprehensive description of the surgical anatomy of testicular maldescent was that of Sir Denis Browne (1938), and most of the views expressed in his classic article concerning the types of undescended testicles, their clinical and operative features, and their prognostic implications are now universally accepted. Browne classified the retained testis into the truly undescended or incompletely descended organ which halts somewhere along its normal route of descent, and the ectopic or maldescended testis which, having traversed the inguinal canal, is diverted from its course to an abnormal position [4].

The intra-abdominal position of the fetal testis was known to Galen, but von Haller (1755) (Fig. 1) and John Hunter (1762) (Fig. 2) were the ones who drew attention to the descent of the testis during late intrauterine life and who recognized and described the gubernaculum as a fibromuscular cord connecting the testis to the scrotum [5].

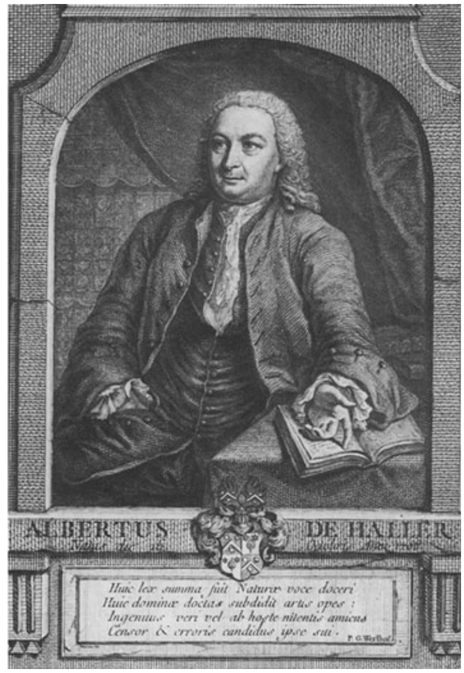

Fig. 1 Baron Albrecht von Haller was the first to accurately describe the abdominal position of the fetal testis in 1755 [5]

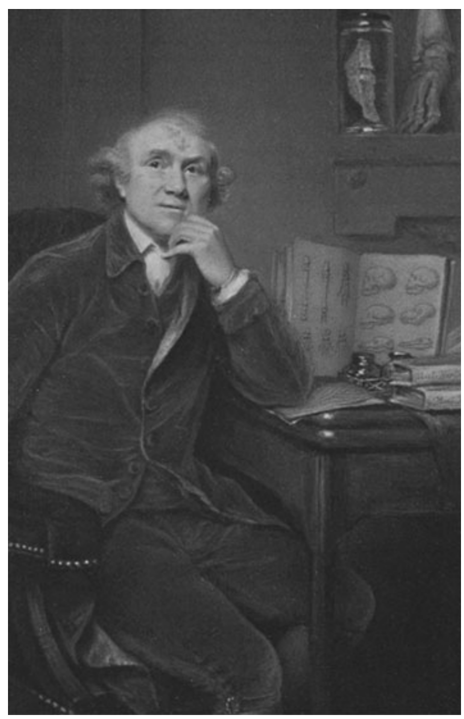

Fig. 2 Hunter's greatest contribution lies in his example and his statement: "why think? Investigate" [5]

Diagnosis of the intra-abdominal testis (IAT)

Impalpable testis constitutes up to 20 % of cases suffering from undescended testis. It represents diagnostic and therapeutic challenge as it may be intra-abdominal, canalicular, pepping at the deep inguinal ring, atrophic or may be absent [6, 7]. Diagnosis of such pathology includes clinical examination, abdomino-pelvic ultrasonography (US), computerized tomographic scanning (CT) of the abdomen and pelvis, magnetic resonance imaging (MRI) and diagnostic laparoscopy.

The imaging techniques are time consuming, expensive and could neither confidently locate the impalpable testis nor exclude its absence [8].

Ultrasound (US)

Wolverson and colleagues [9] reported some success in detecting an IAT by ultrasound using a high frequency 7–10 MHz transducer, which offers better resolution for superficially located organs. The accuracy of ultrasonography depends on the skill of the operator and the amount of subcutaneous fat of the patient. It avoids the use of ionizing radiation and it is cheaper than CT, but it may be difficult to perform in very young uncooperative patients [10].

Computed tomography (CT)

Green in a study of 36 impalpable testes reported failure of computed tomography to localize exactly the testis in 19 patients, representing 52.78 % of patients. These false negative results occurred predominantly in children less than 5 years of age. All testes not detected by CT scan measured greater than 1 cm except one [11].

Magnetic resonance imaging (MRI)

MRI proved to be a useful investigational method and is accurate in depicting testes within the inguinal canal, although it is less accurate for intra-abdominal testes [12]. There is no much evidence that MRI is better than CT for detecting intra-abdominal testes in adults. Despite that MRI has advantages in pediatric patients, there are currently some disadvantages to MRI including:

1. The long scanning time which is sometimes poorly tolerated by children, although improvement in MRI technology has shortened the image acquisition time.
2. Sedation is needed for optimal studies in younger children.
3. The expense is higher than ultrasound or CT scan [13].

Other techniques for localization

Gatti et al. [14] suggested bimanual digital rectal examination under anesthesia as a tool to locate the impalpable testis prior to laparoscopy or inguinal exploration. He showed sensitivity of 60 % and specificity of 100 %.

Snodgrass et al. [15, 16] suggested that initial scrotal incision would save unnecessary laparoscopy in some cases. The finding of atrophic nubbin or extra-abdominal testis not palpated before surgery would preclude laparoscopy.

Kanemoto et al. [17] suggested that initial inguinal exploration followed by transinguinal laparoscopy for nonpalpable testis might become a reasonable alternative, although it is not popular.

Laparoscopy

Recently, diagnostic laparoscopy has been advocated as a safe and effective method for identifying the site of impalpable testis [18]. Diagnostic laparoscopy for impalpable testis was first carried out in 1976 by Cortesi and others [19]; since then, it has gained a great acceptance. Moreover, laparoscopy is now considered as an integral part in the management protocol of nonpalpable testis [20].

Jordan et al. [8] introduced the therapeutic application of laparoscopy in boys with impalpable testes. With advancements in laparoscopic techniques and instrumentation, laparoscopic orchiopexy has become the treatment of choice in boys with impalpable testes. There are no imaging methods that have the same sensitivity and specificity as laparoscopy when there are impalpable testes [21, 22].

High versus low IAT

The decision that an IAT is high or low is named according to the distance between the testis and the internal ring, if more than 3 cm it is considered high [23]. The other test is the “stretching maneuver” or the measuring point [24]. If the testis can be brought to the contralateral internal ring during laparoscopy, it can be brought down to the scrotum without tension. We would like to emphasize that this test has to be done without any tension as sometimes the testis can be brought to the measuring point with some tension, which precludes successful scrotal placement.

Surgical techniques for the intra-abdominal testis

One-stage orchiopexy for the IAT

For the low-lying abdominal testis, one-stage orchiopexy is performed either open or laparoscopically. It depends on the mobilization of the peritoneum, dividing the gubernaculum and taking a straight course for the testicular vessels to the scrotum rather than the angulated normal anatomical orientation (Prentiss maneuver). Excellent results are expected in low-lying abdominal testis, Esposito reported success in 20/20 cases (100 %) [25], Baker et al. [26] in 173/178 cases (97.2 %), and Radmayr et al. [27] in 28/28 cases (100 %).

The Prentiss maneuver

Robert Prentiss in 1959 (Fig. 3) described this technique which significantly shortens the distance that the testis must

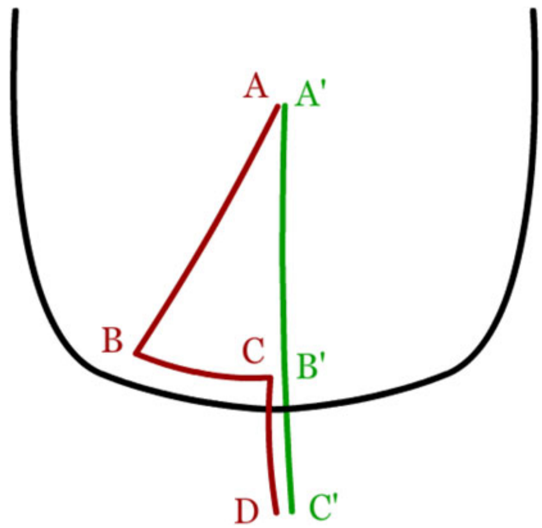

Fig. 3 Robert Prentiss' anatomic triangles allowed a technique to shorten the course of the spermatic vessels by positioning the spermatic vessels medially to the naturally positioned internal ring, thus creating a more direct route to the scrotum by creating a more medial internal ring [29]

travel to reach the scrotum by medial displacement of the testis, and changing an angulated route to a much more direct route to the scrotum. In general, the maneuver is accomplished by taking down the floor of the inguinal canal, moving the spermatic cord to the medial aspect of the canal, and reclosing the floor of the inguinal canal [28, 29].

Techniques for the high IAT

Fowler–Stephens

Despite recent advances in the diagnosis and treatment of the IAT, a short vascular pedicle still represents the greatest threat to place the testis in its normal location at its ipsilateral hemiscrotum with adequate blood supply. To overcome this problem, Fowler and Stephens [30] described division of the spermatic vessels during orchiopexy of a high-undescended testis, depending on the formation of collateral circulation from the inguinal canal and gubernacular vessels for viability of the testicle. A success rate of 50–86 % was achieved using this technique. In 1984, Ransley and coworkers described a staged procedure, ligating initially the spermatic vessels followed by division and placement of the testicle in a scrotal position several weeks later, aiming to improve the formation of the collateral vessels in the undisturbed inguinal canal [31].

In 1991, Bloom [32] applied the same principle and introduced an important modification of clipping the spermatic vessels during laparoscopy. Esposito published the outcome at more than 10 years postoperatively and demonstrated that greater than 83 % of patients who underwent a two-step Fowler–Stephens procedure using laparoscopy had satisfactory results. The operated testis was always significantly smaller compared to the normal testis but was well vascularized [33].

This procedure remains popular for orchiopexy of an intra-abdominal testicle. Although successful outcomes, evaluating the macroscopic aspect of the testicle, have been reported, there is paucity of information regarding the histological repercussion of the ligature of the spermatic vessels of an intra-abdominal testicle during a staged Fowler–Stephens orchiopexy. Rosito in 2004 presented a prospective case study designed to evaluate the viability and compare the histology and volume of intra-abdominal testes before and after ligature of the spermatic vessels. Ligation of the spermatic vessels during the first stage of orchiopexy for intra-abdominal testicles is associated with a significant reduction of spermatogonia. However, no significant changes were observed in the volumetric characteristics of the testicles. Further studies are necessary to evaluate the repercussions of these changes in future fertility [31]. In experimental studies, ligation of the spermatic vessels generated controversial results, depending on the animal model. In Sprague–Dawley rats, clipping of the spermatic vessels reduced testicular blood flow by 80 % at 1 h but it was restored to normal at 30 days without any loss of testicular integrity [34].

Histological examination revealed intact parenchyma and stroma, normal Leydig and Sertoli cell numbers, and mild tubular disturbances. However, in Wistar rats, division of the principal spermatic vessels resulted in atrophy of previously normal testes, interruption of spermatogenesis and interstitial cell dysfunction [35]. Collateral blood flow to the testis was inadequate for normal spermatogenesis and endocrine function.

There are obvious contraindications for the Fowler–Stephens approach which are the presence of dissociation between the testis and epididymis and previous inguinal exploration which precludes adequate collateral circulation between the testis and the vassal circulations [36].

Microvascular autotransplantation

Silber and Kelly [37] described an IAT, in a child with prune belly syndrome, which was successfully transplanted to the scrotum by a microvascular technique. The technique had many proponents [38–44] with the advent of laparoscopy; it was used to assist microvascular technique: laparoscopically assisted testicular autotransplantation (LATA) [45]. The problems with microvascular autotransplantation are the need for expertise and special equipment, and the fact that at the optimum age for performing orchiopexy (6–12 months) the testicular vessels are too small to allow easy anastomosis.

Elongation through traction

The notion of organ gradual traction inducing elongation is elite to be tested in IAT after its documented success in bone and esophagus. In the *New York Medical Journal* in 1909, Franz Torek of New York, a surgeon known for the first successful esophageal resection via thoracotomy, published another surgical technique for the treatment of the undescended testis based on the idea of traction to gain length in a retrograde manner. Torek, without knowledge of a similar operation described by C. B. Keetley in England, described a technique in which the testis was mobilized and fixed to the fascia of the thigh [46, 47]. In contrast to Keetley, who recommended a high division of the cremaster and used cremaster to anchor the testis indirectly to the thigh with an element of traction, Torek proposed that the tunica albuginea be fastened to the fascia lata without tension for 3–6 months. The testis was then detached carefully and the wounds closed. In 64 cases using the Torek method, none of the procedures required division of the spermatic vessels [47].

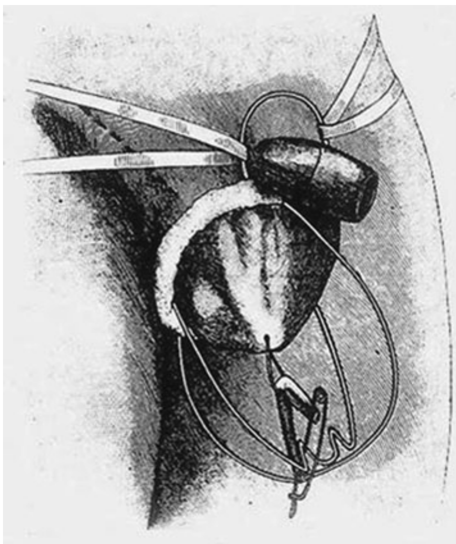

Fig. 4 Leonard Bidwell's external wire cage technique [48, 49]

Cabot and Nesbit of the University of Michigan revisited the concept of continuous traction in 1931, using again a rubber band and wire cage for approximately 12 days. They advocated the use of the procedure for those cases in which adequate repositioning would not be possible without division of the vessels [48, 49].

Leonard Bidwell (Fig. 4), assistant surgeon of the West London Hospital, described a technique for inducing the testis to gain approximately an inch and a half of length, and anchoring the testis to an external wire cage to provide continuous traction.

These techniques fell into disfavor possibly because of excessive and uncontrolled traction, which led to a high and unacceptable rate of testicular loss.

Traction revisited: laparoscopic traction

Recently, the concept of traction to gain length has been revisited. A new approach for the IAT is laparoscopic traction (Shehata technique) (Fig. 5). It involves two

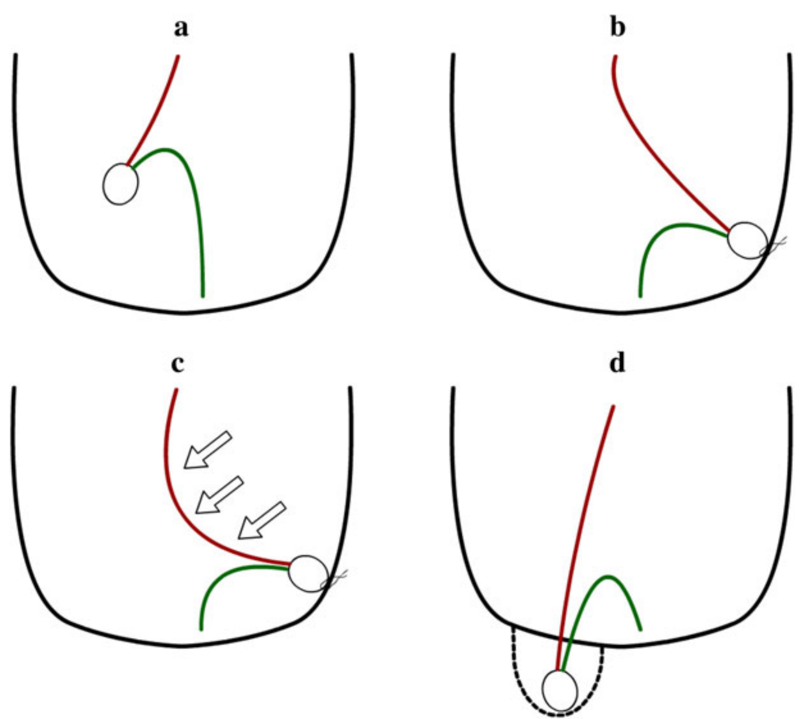

Fig. 5 Laparoscopic traction (Shehata technique) **a** right IAT, **b** stage I: laparoscopic fixation above contralateral anterior superior iliac spine, **c** possible mechanism of elongation by weight of intestine, **d** stage II: laparoscopic-assisted placement in scrotum

stages: laparoscopic fixation of the IAT to a point one inch above and medial to the contralateral anterior superior iliac spine; the second stage is done after 12 weeks, also laparoscopically, and involves dividing the traction stitch and bringing the testis to the scrotum. It has the advantage of bringing down high IAT with intact vessels. The mechanism of elongation is possibly the weight of the intestine working gently and gradually on the testicular vessels to cause lengthening without inducing undue tension or spasm. The preliminary results are very encouraging [50]. The main difference between the current technique and historical trials at traction is that it allows very gradual and gentle traction allowing elongation without jeopardizing testicular viability. The technique has been recently modified with technical refinements, and data of fifty cases with long term follow up is under publication.

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