What radiologist should know about ultrasound diagnosis of inguinal pathology in pediatrics

Poster No.: C-0537
Congress: ECR 2018
Type: Educational Exhibit
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Keywords: Image registration, Education, Ultrasound, Abdomen, Pediatric
DOI: 10.1594/ecr2018/C-0537

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Learning objectives

- To know the anatomy of the inguinal canal and its embryological origin.
- To know the different pathologies that can involve the inguinal canal in pediatrics.
- To review some practical aspects about ultrasonography of the inguinal canal.
Background

The radiological diagnosis of pediatric inguinal pathology is of particular importance given the potential clinical repercussions of an equivocal diagnosis or of a report that omits important information. Sometimes the pathology arises from a congenital abnormality; for example, incomplete closure of the vaginalis process gives rise to a funicular hydrocele, which although benign, could be complicated by a hernia, compromising the viability of the herniated organ (testicles, intestinal loops, ovary). Thus, radiologists need to know the embryological development of the inguinal canal, the resultant anatomy, and the correct ultrasound technique to examine it.

This exhibit uses graphic illustrations and ultrasound images from our pediatric radiology unit, to review the ultrasound findings for the most common conditions that affect the inguinal canal in neonates and children, focusing on abnormalities of the processus vaginalis, such as congenital hydroceles, indirect inguinal hernias, and cryptorchidism.

Anatomy of the inguinal canal (IC)

The IC is a narrow passage in the lower part of the anterior abdominal wall. Measuring approximately 4 cm in length, its run diagonally between the aponeuroses of three muscles: the external oblique, the internal oblique, and the transverse abdominal (2) (Fig.1).

The IC has two openings at both ends: the deep inguinal ring is an oval hollow in the transverse fascia that marks the entrance to the inguinal canal; it lies 1 cm superior to the inguinal ligament and lateral to the inferior epigastric vessels. The superficial inguinal ring, is a triangular opening in the aponeurosis of the external oblique muscle, is the exit point of the inguinal canal. (Fig.1)

In males, the inguinal canal contains the spermatic cord, which includes the vas deferens, the testicular artery, and the genital branch of the genitofemoral nerve; in females, it contains the round ligament of the uterus and the ilioinguinal nerve(1).

Embryological development of the inguinal canal

To understand the anatomical and pathological characteristics of the inguinal canal, radiologists need to know the embryological development of two main structures: the gubernaculum and processus vaginalis.
The gubernaculum is a ligament attached to the inferior pole of the gonad that runs inferiorly through the abdominal wall into the groin where its caudal end attaches to the skin of the fetal groin (labioscrotal fold), which later forms the scrotum or labia major (Fig. 2). In male embryos, the gubernaculum develops into the gubernaculum testis, a string of fibrous and muscular tissue that helps in the descent of the testicle through the IC to the developing scrotum and leaves no remnant in the adult (1). In female embryos, the gubernaculum is usually thinner; its cranial end is attached to the ovaries (later becoming the ovarian ligament) and its caudal end is attached to the inner surface of the labioscrotal fold (later becoming the round ligament of the uterus).

The processus vaginalis is a tubular fold of peritoneum that invaginates in the IC during gestation. It is disposed caudally through the abdominal wall to the scrotum, being located just anterior to the gubernaculum and the developing descending testicle (Fig.2), and before birth by hormonal stimuli it gradually obliterates in a downward direction. In the male fetus, the scrotal section of the processus vaginalis remains patent, forming the testicular tunica vaginalis (Fig.2 and 3). In the female fetus, the whole process normally obliterates before birth; when a patent processus vaginalis persists after birth in females, it is called the canal of Nuck. (3)

Patent processus vaginalis

The processus vaginalis is still patent at birth in 20% of the population (3). Conditions that may be associated with non-obliteration or late closure of this structure include premature birth, cystic fibrosis, Ehlers-Danlos syndrome, hip dysplasia, peritoneal dialysis, or ventricle-peritoneal shunt (3). Most children born with a patent processus vaginalis are asymptomatic throughout their lives.

Persistent patency of the processus vaginalis can result in an undescended testis, communicating hydrocele, or indirect inguinoscrotal hernia. If none of these anomalies are present, persistent patency may go unnoticed.
Fig. 1: Anatomy of the inguinal canal. The inguinal canal (IC) is a short, narrow, diagonal passage in the anterior inferior abdominal wall measuring approximately 4 cm in length, which lies between the aponeuroses of three muscles: the external oblique, the internal oblique, and the transverse abdominal. The IC has openings at both ends: the deep inguinal ring and the superficial ring. The inferior epigastric artery and vein are located medially to the deep inguinal ring.
Fig. 2: Embryology of the inguinal canal. The normal descent of the gonad begins around 28 weeks of gestation; it is guided by the gubernaculum through the inguinal canal. The processus vaginalis is a tubular fold of the peritoneum that forms in front of the gubernaculum and appears around 13 weeks of gestation; the scrotal portion remains patent, forming the tunica vaginalis. The upper section of the processus vaginalis closes at or just before birth. In females, when the descent of the ovary stops in the pelvis, the processus vaginalis finally disappears and the remnants of the gubernaculum become the ovarian ligament and the round ligament of the uterus.

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Fig. 3: The inguinal canal and the scrotum. Note the obliteration of the upper part of the processus vaginalis. During development, extensions of all layers of the abdominal wall accompany the processus vaginalis and contribute to the formation of the inguinal canal and scrotum walls.

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Findings and procedure details

We review some practical aspects for optimizing ultrasound studies of the IC: types of probe and probe placement to obtain the correct planes, which images to acquire, and anatomical reference points. We present the most characteristic ultrasound findings for each condition.

Ultrasound technique for the evaluation of the IC

Ultrasound enables real-time imaging during the patient’s dynamic maneuvers, and the ultrasound techniques used to study the IC should be optimized based on the clinical question being investigated.

Normally, high-frequency linear transducers (18-9 MHz multifrequency) suffice; although exceptionally low frequency curved ultrasound transducers are required. In patients with focal symptoms with inconclusive findings, comparative views of the contralateral side can be helpful.

To facilitate the acquisition of ultrasound images of the IC in a boy, it is best to start the study through the scrotum, using an ascending sagittal section to identify the distal end or superficial ring of the IC. After this landmark is identified, we continue upward until the anterior rectus muscle is visualized forming an open angle, thus covering the entire path of the IC. (Fig. 4)

On ultrasound, the IC is seen as a linear structure with a double contour (Fig. 5). Under normal conditions, its thickness is approximately 4 mm or less. To ensure correct visualization and evaluation, it is important to avoid compressing the canal.

Congenital hydroceles

Congenital hydroceles result from abnormal closure of the processus vaginalis. They are present in 6% of male children at delivery and most hydroceles resolve before 2 years of age (1) (3) (13). In older children and adolescents, hydroceles are usually acquired, as a result of an inflammatory process. In the normal scrotum, 1-2 ml of serous fluid can be seen in the tunica vaginalis and should not be confused with hydrocele (13).
There are three types of hydrocele of the male IC: communicating, funicular, and cystic (Fig. 6).

1. **Communicating hydrocele or abdominoscrotal hydrocele** is a very rare entity, associated with the complete patency of the processus vaginalis (13). On ultrasound, it appears as a fluid collection that extends from the pelvis through the deep inguinal ring to the scrotum (Fig. 7 and 6C). These large inguinoscrotal hydroceles commonly coexist with indirect inguinal hernias, so herniorrhaphy is performed.

2. **Funicular hydrocele** results from an abnormal constriction of the processus vaginalis just above the testicle. On ultrasound, it appears as a fluid collection that communicates with the peritoneum and that does not surround the testicle (Fig. 8 and 6B). It usually increases with Valsalva maneuvers. Funicular hydroceles are considered a type of potential indirect hernia that, when large, can compromise testicular viability by compression; thus, herniorrhaphy is usually performed.

3. **Cystic hydrocele or cord cyst** is enclosed between two constrictions, one at the level of the deep inguinal ring and one just above the testis. Cystic hydroceles do not communicate with the peritoneum; they can be located anywhere along the spermatic cord and can be any size, but do not change with Valsalva maneuvers. Ultrasound shows a cystic ovoid or round image in the IC (Fig. 9 and 6A).

**Nuck cyst and Nuck hernia**

These two rare entities occur in females when the Nuck canal fails to obliterate (analogous to a persistent processus vaginalis in males) (Fig. 10).

A Nuck cyst is usually a painless, irreducible, mobile inguinal mass, that can be transilluminated. The diagnosis can be easily established with ultrasound, which shows a cystic mass with a thin echogenic edge (Fig. 11). A concomitant inguinal hernia is usually associated (Nuck’s hernias). These hernias can also be ruled out by the same ultrasound technique. In 15% to 20% of cases of Nuck’s canal herniation, the ovary enters the canal (Fig. 12 and 13), sometimes accompanied by a fallopian tube. Ovaries trapped in hernias are at risk of torsion and / or incarceration (5). Early diagnosis is crucial, because in cases of incarcerated ovary or strangulated loops, surgical excision is the treatment of choice (6) (10).

**Hematocele**

A hematocele is the accumulation of blood within the parietal and visceral layers of the tunica vaginalis. Hematoceles can result from trauma, torsion, tumor, or surgery. The ultrasound appearance varies depending on the age of the blood products; hematoceles...
are often described as heterogeneous lesions with echoes and low level septa, and they can sometimes become fibrotic and calcified (Fig. 14).

Communicating hematoceles have also been reported in cases of patent processus vaginalis, as a result of the extension of the hemoperitoneum to the scrotal sac (e.g., after splenic rupture or perforated Meckel's diverticulum) (5) (11).

**Inguinal hernia**

To classify inguinal hernias into direct and indirect hernias, it is useful to determine their origin with respect to the inferior epigastric artery. Indirect inguinal hernias originate lateral to the inferior epigastric vessels, while direct inguinal hernias originate medially to the inferior epigastric vessels (5) (12). In pediatrics, all hernias are indirect (associated with a patent processus vaginalis).

Inguinal hernias can also be classified as reducible, incarcerated, and strangulated. The term **incarceration** is used for cases where the organ herniated in the IC is trapped outside the abdomen and cannot be reduced (Fig. 15 and 16). If the incarcerated hernia is not treated, it can evolve to **strangulation**, which is when the blood supply of the organ (the intestine, testicle or ovary) is compromised, causing ischemic injury (Fig. 16).

Color Doppler ultrasound helps determine whether ischemia has developed in the contents of the hernia sac. Hyperemia is usually seen in advanced enclosed hernias that begin to show signs of possible strangulation (Fig. 15); the absence of blood flow is usually not seen until later stages (Fig. 16).

Inguinal hernias usually contain intestinal loops with associated epiploic fat (Fig. 17) or epiploic fat alone (Fig. 18). On ultrasound, a herniated omentum is seen as an elongated echogenic structure, which should not be confused with a bowel loop since it does not present peristalsis, wall, or content.

The diagnosis of inguinal hernia is basically clinical, and ultrasound is reserved for inconclusive cases. On ultrasound, an IC width of more than 4 mm at the level of the internal inguinal ring has a high probability of evolving into a hernia (5); in these cases the Valsalva maneuvers help to identify the presence of a hernia.

**Cryptorchidism**
Undescended testes, or cryptorchidism, result from an interruption in the normal descent of the developing testes on their way to the scrotum. After the first year of life, spontaneous descent is uncommon. Cryptorchidism is unilateral in 90% of cases (1).

Cryptorchidism can be classified by the location of the incompletely descended testis as abdominal or intraabdominal testis (10%), inguinal or canalicular testis (70%), and suprascrotal or high scrotal testis (20%). (13). (Fig. 19)

Undescended testes have an increased risk of torsion and infertility (12). Clinically, patients with cryptorchidism usually have an empty scrotal sac, with or without a palpable mass in the groin (Fig. 20). Ultrasound has high precision for the location of an undescended testis. The technique consists of tracking the entire IC. When the testes are not located inside or distal to the IC, an intra-abdominal location should be suspected.

Most undescended testes are hypoechoic and relatively small (Fig. 21). Color Doppler helps determine testicular viability by demonstrating the presence of blood flow.

In young children, the presence of a testis in the IC can also represent a retractable testis. Up to 50% of children younger than 11 years old have at least one retractable testis (1). The treatment of choice for undescended or retractable testes is orchidopexy before 2 years of age to avoid subsequent testicular damage (3) (12).

Varicocele

Varicoceles are the masses most frequently found in the spermatic cord (5). They usually occur in adolescents, and less frequently in children before puberty(8). Primary or idiopathic varicoceles are associated with incompetent valves of the pampiniform plexus, leading to deterioration in venous drainage and subsequent dilation of the pampiniform plexus veins. Primary varicoceles are more common on the left side (1). Secondary varicoceles are caused by increased pressure in the testicular vein as a result of intraabdominal pathological processes (1). Symptoms include a palpable soft mass in the groin, pain, discomfort, and infertility (1).

Ultrasound shows varicoceles as serpiginous anechoic tubular structures, with a "worm bag" appearance, along the inguinal canal (Fig. 22). To establish the diagnosis, the veins of the pampiniform plexus must be greater than 2-3 mm in diameter (1). The visibility of the veins increases with the Valsalva maneuver. Surgery is indicated only when asymmetric testicular volume is demonstrated.

Inflammatory conditions that affect the IC
Infectious or inflammatory conditions that affect the IC include lymphadenopathy or abscesses, which usually represent an extension of an intraabdominal or scrotal infectious process.

- **Pyoceles** resulting from intra-abdominal processes occur in boys with a patent processus vaginalis and are related to the declining location of the scrotum, which favors the accumulation of pyogenic exudate. Hematogenous infection that induces pyocele has been reported in association with *Haemophilus influenza* and septicemia due to *Escherichia coli*. (5) On ultrasound, an abscess appears as a heterogeneous and complex collection of fluid. Gas may be present, causing bright echoes and shadows. (Fig. 23). Patients present with an acutely painful, swollen scrotum, elevated white blood cell count, and fever.

- **Acute idiopathic scrotal edema** is characterized by the acute onset of relatively painless scrotal erythema and subcutaneous edema, which resolve spontaneously, without sequelae, in 1-3 days (5). Is the most common cause of acute scrotum in prepubertal boys (5). Erythema and edema usually extend to both inguinal areas and may also reach the abdomen, perineum, and penis. The characteristic ultrasound findings include marked thickening of the scrotal wall and inguinal areas with a heterogeneous edematous appearance (sometimes "in onion layers"), increased of color Doppler signal of the scrotal cover (fountain sign), mild reactive hydrocele, and increased size of the inguinal lymph nodes (5) (14) (Fig. 24). The diagnosis is mainly by exclusion, which requires the confirmation of the presence of normal testicular arterial flow in color Doppler ultrasound. Differentiating idiopathic acute scrotal edema from a scrotal surgical emergency such as testicular torsion is essential to avoid unnecessary surgery.
Fig. 4: Ultrasound technique for evaluation of the inguinal canal. Start the study through the scrotum, using an ascending sagittal section to identify the distal end of the inguinal canal (superficial ring); continue upward until the anterior rectus muscle is visualized forming an open angle.

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Fig. 5: Inguinal canal by ultrasound. The image shows a sagittal section of the inguinal canal. The study begins in the scrotum; the first landmark is the testicle (star), ascending from which we should visualize the rectus abdominis muscle (yellow line). On ultrasound, the inguinal canal appears as a linear structure with a double contour (green lines). Under normal conditions, the inguinal canal is approximately 4mm thick. Through the inguinal canal, the spermatic cord (including the vas deferens, the testicular artery, and the genital branch of the genitofemoral nerve) passes, and Doppler imaging confirms the presence of a vascular signal (arrow).

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Fig. 6: Classification of congenital hydroceles. A) In a non-communicating cystic hydrocele or cord cyst, the fluid is trapped in the remnant of the processus vaginalis. B) In a funicular hydrocele, the fluid collection in the inguinal canal communicates with the peritoneal cavity, but not with the scrotum. C) In a communicating (abdominoscrotal) hydrocele, there is fluid communication between the peritoneal cavity and the scrotum due to the complete patency of the processus vaginalis.

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Fig. 7: Ultrasound in a 6-month-old boy with suspected inguinal hernia shows a bilateral tension hydrocele (green arrows), with an intra-abdominal component (red lines); color Doppler study shows both testes are preserved and symmetric (white arrows). Note the communication / bilateral defect of the deep inguinal ring (yellow arrows). This bilateral communicating hydrocele with intra-abdominal component was treated with bilateral herniorrhaphy.

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Fig. 8: Ultrasound images from a 4-year-old boy with left testicular trauma in whom the left testis was not palpated in the emergency department. A well-defined anechoic image is observed inside the left scrotal sac (blue arrow), which ends in the cul-de-sac (green outline) and continues with the inguinal canal and displaces the testicle inferiorly (red arrow). The testicle showed preserved color Doppler signal (yellow arrow). The lesion was considered a left funicular hydrocele and the patient was scheduled for surgery.
**Fig. 9:** Ultrasound images in a 2-month-old boy with suspected left inguinal hernia show a cystic, oval, anechoic lesion with thin walls (yellow arrows) in the left inguinal canal. The testis was visualized without alterations (star). Stenosis of the processus vaginalis (red arrows) was identified just above and below the cystic structure. The lesion was considered a probable cord cyst or cystic hydrocele

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Fig. 10: A) Nuck’s cyst in the inguinal canal. B) Nuck’s cyst in the labia major. Female hydrocele, also called Nuck’s cyst. The evagination of the parietal peritoneum is the Nuck canal in females. The Nuck canal usually undergoes complete obliteration during the first year of life, and failure to obliterate results in a hydrocele of the Nuck canal, sometimes a potential indirect inguinal hernia.

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Fig. 11: Ultrasound images in 4-year-old girl with a painless inguinal mass show a cystic image (star) at the distal end of the inguinal canal, compatible with female hydrocele or Nuck canal cyst.
Fig. 12: Ultrasound of the right inguinal area in a 7-week-old girl with a palpable inguinal mass done to differentiate between a hernia and an adenopathy shows a hernial defect / Nuck canal (white arrows) through which the herniated right ovary protrudes (yellow arrows); Doppler flow is preserved (green arrow). These findings are compatible with Nuck canal hernia with ovarian content. Inguinal herniorrhaphy was performed, and the apparently viable ovary was reduced to the abdominal cavity without further complications.

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Fig. 13: Inguinal ultrasound in a 6-week-old girl with a palpable inguinal mass shows persistence of the processus vaginalis or Nuck's canal (red arrows) as an oval image with protruding microcysts corresponding to the right ovary (yellow arrows) and a small amount of fluid around it (star). The color Doppler signal in the ovarian parenchyma was preserved (white arrow). The orientative diagnosis was a hernia of the right Nuck canal with ovarian content. Inguinal herniorrhaphy was performed with reduction of the viable ovary to the abdominal cavity.

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**Fig. 14:** Ultrasound in a 4-month-old boy done 48 hours after trauma causing an enlarged, erythematous scrotum shows significant thickening of the scrotal covers (yellow contours). In the lower part of the right inguinal canal (red contours) and extending into the intrascrotal space, a large anechoic collection is observed (blue arrows), with multiple septa inside (green arrows) that contact and displace the testicle (star). Right testicle of normal size and morphology with preserved Doppler signal (white arrow). Findings compatible with traumatic hematocele

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**Fig. 15:** Ultrasound in a 1-month-old boy with suspected testicular torsion shows a patent processus vaginalis at the level of the deep inguinal ring (green arrows), through which intestinal loops protrude (red arrows) towards the scrotal sac. The loops presented peristalsis and increased color Doppler signal, and a large ipsilateral hydrocele (blue arrow) was associated. The Doppler signal (yellow arrow) was present in the testis. The orientative diagnosis was an incarcerated inguinoscrotal hernia.

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Fig. 16: Male patient of 25 days of age with a non-reducible right inguinal bulge. The ultrasound shows a right inguinal hernia with an intestinal loop inside it (red arrows), without being able to visualize color Doppler signal in the right testicle (star), and very little Doppler signal in the herniated loop (white arrows). Reactive hydrocele and some septum were observed inside the scrotal sac (blue arrow) and thickened scrotal covers (green arrows). The case was oriented as a strangulated right inguinal hernia that compromised the testicular flow by compression.

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Fig. 17: Ultrasound in a 4-week-old boy with suspected right testicular torsion shows a right inguinal hernia (red arrows), with contents of bowel loops and omentum (star) inside the scrotum, with edema of the herniated intestinal wall (yellow contour), and with intramural air bubbles (blue arrow). The defect is appreciated at the level of the deep inguinal ring (white arrows). Note the thickened scrotal lining and bilateral hydrocele (green arrows). Right testicle with preserved Doppler signal (yellow arrow). The orientative diagnosis was a right inguinoscrotal hernia with possible pneumatosis of the herniated intestinal loop. The patient underwent unilateral herniorrhaphy, where no evidence of pneumatosis was observed.

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Fig. 18: Ultrasound in a 3-year-old boy with scrotal pain shows a right scrotal inguinal hernia with fatty content / omentum (yellow arrows). The diameter of the inguinal canal was increased (9mm), and there was fluid in the scrotal sac (white arrow). The testicles showed no alterations (blue arrow). The orientative diagnosis was a right inguinal hernia with omentum inside.

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**Fig. 19:** Classification of cryptorchidism according to the location of the poorly descended testicle in relation to the inguinal canal: abdominal or intraabdominal testicle 10% (red), inguinal or canalicular testis 70% (orange), and suprascrotal 20% (green)

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**Fig. 20:** Ultrasound in a 6-month-old boy in whom the left testicle was not palpated in the scrotal sac shows asymmetric diameters of the two inguinal canals, the right one is 2.8 mm and the left one is almost 6 mm. The right testicle (blue arrow) was in the scrotal sac, while the left testicle (red arrow) was located at the proximal end of the inguinal canal with a small associated hydrocele that facilitated its correct visualization. The Doppler study of both testicles was symmetric. The case was considered left cryptorchidism.

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**Fig. 21:** Ultrasound in a 1-year-old boy in whom the right testicle was not palpated in the scrotal sac shows a hypoechoic right testicle (red arrow) located at the proximal end of the inguinal canal, an empty scrotal sac (star). The orientative diagnosis was cryptorchidism and hypoplasia of the right testicle.

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Fig. 22: Ultrasound in a 14-year-old boy with scrotal discomfort identifies vascular tubular structures > 2mm with increased Doppler flow after the Valsalva maneuver. The diagnosis was left varicocele.

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Fig. 23: Ultrasound in a 4-week-old boy with right scrotal edema and erythema associated with an infected surgical wound after treatment for hypertrophic pyloric stenosis shows a multiseptated right hydrocele (red arrows) with thickening of the scrotal linings (blue arrows). Doppler signal was increased in the scrotal linings (yellow arrows) and in the right testis (white arrow). Symmetric epididymides of normal morphology. The diagnosis was a right pyocele with multiple septa. The patient had E. coli septicemia from the infected surgical wound.

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Fig. 24: Ultrasound in a 2-year-old boy with inflammation and bilateral testicular erythema shows marked thickening of the scrotal linings (discontinuous yellow lines), increased color Doppler signal of the scrotal lining "fountain sign" (white arrows), scarce reactive hydrocele (blue arrows), and both testes and epididymides with color Doppler signal preserved. The orientative diagnosis was idiopathic scrotal edema.

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Conclusion

Inguinal canal complaints are common in children. Various pathologies can affect the inguinal canal. It can be challenging for radiologists to detect and establish the correct diagnosis of the different IC pathologies. Adequate knowledge of the topographic anatomy, the embryology of the inguinal region, and the ultrasound technique is essential, as is recognizing the most common disorders, mainly related to the persistence of the processus vaginalis, such as hydroceles, indirect inguinal hernias, and cryptorchidism. It is important to know the different types of congenital hydroceles and their potential clinical repercussions to indicate early surgical intervention and avoid unwanted clinical damages.
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