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Laboratory Investigations

Ultrasound-guided dissection and ligation of the internal inguinal ring for hernia repair in pediatrics: an experimental animal study☆

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ABSTRACT

Purpose: We aimed to test the feasibility and reliability of ultrasound-guided percutaneous internal inguinal ring suture in rabbits, as a model for inguinal hernia repair in pediatric population.
Methods: Twenty-eight rabbits were divided in 2 groups: group I (female morphology) - persistence of the peritoneal–vaginal duct with gonads placed in intraperitoneal position; group II (male morphology) - persistence of the peritoneal–vaginal duct with gonads kept intact inside the duct. Under exclusive ultrasound-guided image we tried to perform a complete pre-peritoneal ligation of the peritoneal–vaginal duct at the level of the internal inguinal ring using a 20G peripheral IV catheter and 2–0 non-absorbable suture. Afterwards, an exploratory laparoscopy was performed to evaluate the ligation.
Results: Ultrasound allowed characterization of inguinal–crural structures. Group I – complete and reliable suture 66.7%, incomplete but reliable suture 16.7%, inappropriate ligation 16.7%; group II – complete but unreliable suture 76.9%, incomplete and unreliable suture 11.5%, inappropriate suture 11.5%. No acute complications were logged.
Conclusions: Percutaneous dissection and ligation of internal inguinal ring through exclusive ultrasound guidance was feasible and likely reliable, namely for female inguinal hernia repair.

Since the dawn of laparoscopy, minimally invasive surgery has been spreading worldwide. As the techniques evolve, new strategies have been applied, as the use of natural orifices, robotically assisted procedures and percutaneous laparoscopic assisted procedures, in a quest to be even less invasive. While the open techniques for indirect inguinal hernia correction, a common procedure in pediatric surgery, are well established and have had their own evolution, laparoscopic correction has emerged in this global context [1,2], peaking nowadays for some into a scar less percutaneous procedure [3].

Simultaneously, the ultrasound technology has evolved greatly, with the technology becoming more available and being currently used in areas other than radiology and diagnostics. The ultrasound-guided loco-regional anesthesia is a well-established example of the ultrasound utility in a surgical setting [4,5]. Likewise, ultrasound imaging is for some the diagnostic exam for a groin hernia [6,7] as well as a resource that can be accurately used by a surgeon as a diagnostic tool [8,9].

Aiming for an even less invasive procedure, based in the laparoscopic assisted procedure experience, we postulate that an ultrasound-guided internal ring suture (UGIRS) could be a reproducible, feasible, reliable and safe procedure for indirect inguinal hernia in pediatric female patients, avoiding the inherent risks of an abdominal cavity entry and pneumoperitoneum. Therefore we conducted this study in an animal model aiming to prove this concept. To accomplish this, we performed an UGIRS in a living rabbit model using a 20G peripheral IV catheter and a 2/0 monofilament non-absorbable suture, dividing the study into two groups, being the first a simulation of the human female indirect inguinal hernia and the second a simulation of the male's morphology. To our knowledge, this is the first study that evaluates the role of ultrasound imaging in percutaneous repair of inguinal defects.

1. Materials and methods

The New Zealand male rabbit was the selected animal model since it has a patent *processus vaginalis* [10] where an inguinal ring (IR) suture can be performed [11]. Also, this is a low cost animal model, with a comparable size to the newborn, making it a popular model for surgical training. Moreover its anatomy is well known, particularly the main landmarks of inguinal ultrasound evaluation [12,13]. The relation between these landmarks are different than in the human, nevertheless

☆ Conflict of interests: none.

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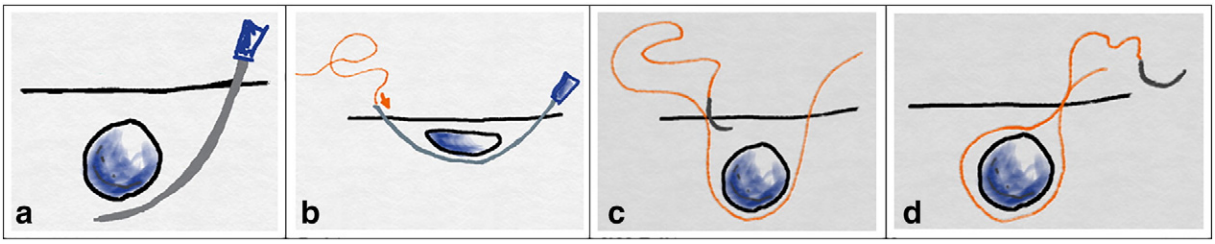

Fig. 1. Schematics of procedure's main steps.

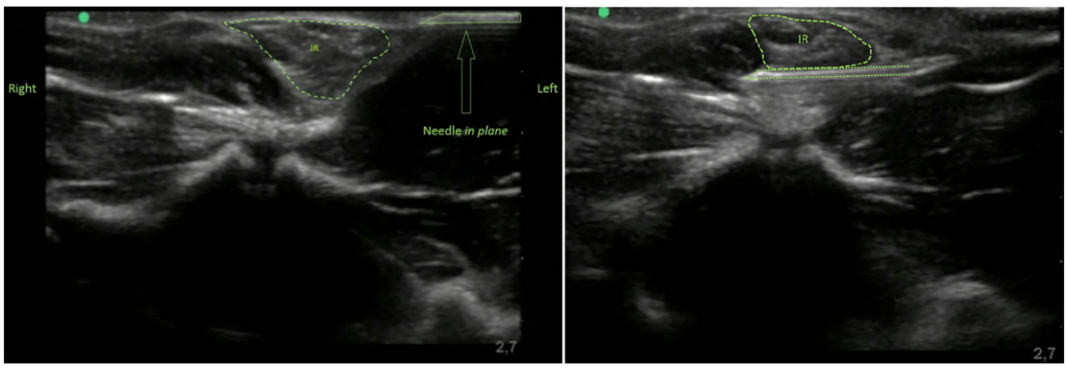

Fig. 2. Ultrasound stills during in plane needling technique of UGIRS.

our study aims to evaluate an exclusively ultrasound-guided percutaneous suture of the internal inguinal ring, placed in an extraperitoneal position; therefore we considered this model suited for our purpose.

Under general anesthesia (ketamine 25 mg/kg + medetomidine 0,3 mg/kg subcutaneous), the rabbit is submitted to trichotomy and placed in Trendelenburg position. In the first group of the study, testes are placed in an intraperitoneal position through a laparoscopic approach using a 5-mm 30° laparoscope medially and 3-mm scissor and grasper laterally on each side, leaving the patent *processus vaginalis* void of content and simulating the female Nuck's duct. Pneumoperitoneum is evacuated. In the second group no further manipulation was done prior to the UGIRS. Using a 13-MHz linear ultrasound probe, anatomical landmarks are identified (inferior epigastric artery emergence, ileofemoral vessels, inguinal ligament, patent *processus vaginalis* and IR) and the duration of this step recorded.

With a previously bended 20G peripheral IV catheter, the rim of the IR is punctured laterally and the needle oriented under the IR from side to side, circumscribing the IR (Fig. 1a). The puncture is done under exclusive ultrasound visualization using an *in plane needling* technique, with the probe fixed over the IR in a transverse plane (Fig. 2). The end of a monofilament non-absorbable 2/0 suture is inserted through the catheter's lumen (Fig. 1b) and the latter removed. The suture's needle is then oriented subcutaneously back from the skin's second puncture site to the first (Fig. 1c and d) and secured with a mosquito forceps.

The time of the procedure is logged. A second landmark identification and UGIRS are performed in the contralateral inguinal region, in the same fashion. A 5-mm 30° laparoscope is then placed through a medial port and a 3-mm grasper inserted through a stab-wound. At this stage, for each side, the IR suture success is verified and catalogued within the previously established categories: complete and reliable ligation (Fig. 3), incomplete but reliable ligation (Fig. 4), complete but unreliable ligation (Fig. 5), incomplete and unreliable ligation (Fig. 6), inappropriate ligation – the latter regarding distal ligations without closing the IR or with a major gap. To better appreciate the ligation result, the knot was loosened and tightened during exploratory laparoscopy, in a dynamic fashion. (See Figs. 7 and 8.)

Complications and organ damage were also searched. Note that the procedure results are verified in a dynamic fashion, with the knot tied and loosened. After the completion of both the procedures and

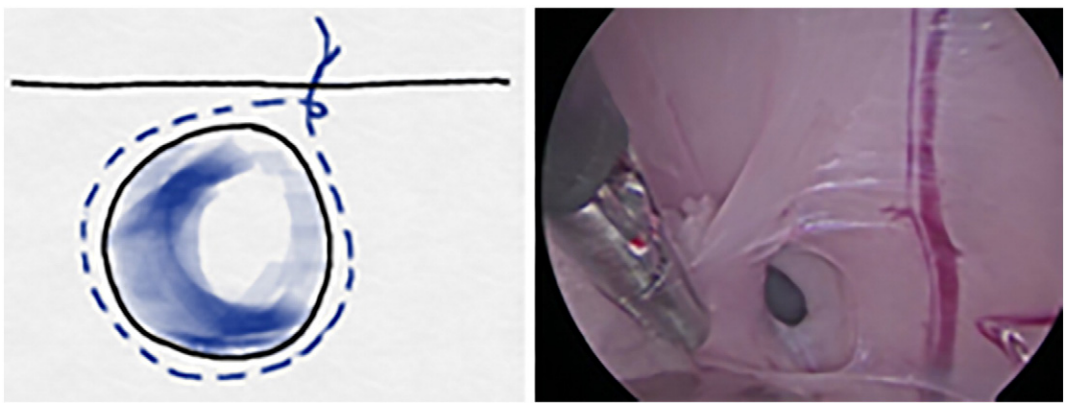

Fig. 3. Complete and reliable ligation schematics and laparoscopy photo. No gap and without spermatic cord entrapment.