3D Endoanal Ultrasonographic Changes in Anorectal Morphologic Parameters after Fistula-in-ano Surgery

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Abbreviations

- **2D-EAUS:** Two Dimensional Endoanal Ultrasound.
- **3D-EAUS:** Three Dimensional Endoanal Ultrasound.
- **ABS:** Artificial Bowel Sphincter.
- **ACD:** Anal Canal Length.
- **ACL:** Anal Canal Diameter.
- **AI:** Anal Incontinence.
- **CCF-FI:** Cleveland Clinic Florida Fecal Incontinence score.
- **CLL:** Conjoined Longitudinal Layer.
- **DV:** Dynamic Viscosity.
- **EAS:** External Anal Sphincter.
- **EFO:** External Fistulous Opening.
- **EMG:** Electromyography.
- **IAS:** Internal Anal Sphincter.
- **IFO:** Internal Fistulous Opening.
- **IRP:** Intra-rectal Pressure.
- **JW:** Jorge Wexner score.
- **LM:** Longitudinal Muscle.
- **PA:** Puboanalis muscle.
- **PAS:** Prosthetic Anal Sphincter.
- **PC:** Pubococcygeus muscle.
- **PNTML:** Pudendal Nerve Terminal Motor Latency.
- **PR:** Puborectalis muscle.
- **TP:** Transverse perinei muscles.

Introduction

Perianal fistulae are an ongoing problem requiring appropriate treatment planning to minimize the risk of recurrence and postoperative fecal incontinence. The surgical treatment may vary depending on the preoperative classification of the fistula and its relationship to the sphincters ***(Seow-Choen and Nicholl, 1992).***

With two-dimensional endoanal ultrasound (2D-EAUS), the actual spatial relationships between some elements are hard to perceive, thus losing information. This is a supportive exploratory test that offers qualitative information on the height and tract of the fistulae. However, three-dimensional endoanal ultrasound (3D-EAUS) offers the possibility of obtaining a view in all spatial directions. After performing the 3D-EAUS, the examiner can obtain coronal, sagittal and axial images and accurately measure angles, distances, areas and volumes. This supplies both qualitative and quantitative information. The information required can be assessed by rotating, inclining and cutting the 3D image in many directions. These qualities allow us to measure the exact length of the anal sphincters, and thecorresponding lesion, improving the interpretation of the results and offering additional information to that obtained from physical examination and 2D-EAUS. A more accurate diagnosis contributes to obtaining a higher cure rate and decreases the risk of fecal incontinence ***(Gravante and Giordano, 2008).***

In 2010 Garcés et al. had classified the fistulae using the 3D-US according to their primary tract, as:

- ○ Not visualised.
- ○ Intersphincteric: the tract crosses the intersphincteric space without crossing EAS fibers.
- ○ Low transsphincteric: affects less than 66% of the EAS.
- ○ High transsphincteric: affects 66% or more of the EAS.
- ○ Suprasphincteric: the tract crosses the intersphincteric space surrounding the upper edge of the puborectalis.
- ○ Extrasphincteric: the tract is found to be outside the EAS.

The objectives of this study were to use 3D-EAUS to quantify the extent of the perianal fistula preoperatively and the extent of sphincter division after fistula-in-ano surgery postoperatively with respect to total sphincter length, to detect postoperative anal sphincter lesions and correlate these results with postoperative fecal incontinence in symptomatic and non-symptomatic patients.

This will be a prospective study that will involve twenty patients diagnosed with perianal fistulae; they will be subjected to physical examination, examination by 2D-EAUS followed by 3D-EAUS before and 4 weeks after surgery after obtaining an informed consent. Patient´s clinical history will also be taken into account with particular attention to preoperative continence.

1. ***Physical examination*:**

   Physical examination will be done for localization of the external fistulous orifice (EFO), and the internal fistulous orifice (IFO) with special attention paid to the existence of a secondary tract.

2. ***Ultrasound:***

   The patient is examined in the left lateral position with the probe inserted through the anus. The ultrasound is performed systematically from the upper third to the lower third of the anal canal. First, a 2D-EAUS examination is performed followed by a 3D-EAUS. In cases where the EFO is found open, both examinations are repeated and hydrogen peroxide (10%) is injected with a cannula.

   - 2D-US:

     We evaluate the visualization of the IFO empty or with hydrogen peroxide injected. The primary fistulous tract is classified following a modified Parks classification ***(Parks et al., 1976)*** as:

     ○ Not visualised.

     ○ Intersphincteric: the tract crosses the intersphincteric space without crossing fibers of the external anal sphincter (EAS).

     ○ Low transsphincteric: the tract crosses the EAS or both sphincters in the most distal two thirds of the anal canal.

○ High transsphincteric: the tract crosses both sphincters in the high third of the anal canal.

○ Suprasphincteric: the tract crosses the intersphincteric space surrounding the upper edge of the puborectalis.

○ Extrasphincteric: the tract is found to be outside the EAS.

Other data obtained with this technique are the presence of secondary tracts and the existence or not of perianal cavities and abscesses.

● 3D-US:

A three-dimensional ultrasound is then performed without removing the probe, which allows us to obtain sagittal and coronal images of the anal canal. We reassess the site of the IFO, the primary tract of the fistula and the possible secondary tracts and abscesses corroborating and improving the information obtained from the 2D-EAUS. We classify the fistulae using the 3D-US according to their primary tract, as:

○ Not visualized.

○ Intersphincteric: the tract crosses the intersphincteric space without crossing EAS fibers.

○ Low transsphincteric: affects less than 66% of the EAS.

○ High transsphincteric: affects 66% or more of the EAS.

○ Suprasphincteric: the tract crosses the intersphincteric space surrounding the upper edge of the puborectalis.

○ Extrasphincteric: the tract is found to be outside the EAS.

Quantitative millimeter measurements are taken in all patients of the following variables: total length of the anal canal, length of the puborectalis muscle, length of the EAS and length of the IAS. The percentage of involved EAS and IAS by the fistula is calculated preoperatively, and the percentage of divided sphincter is calculated after fistula surgery ***(Garcés et al., 2012).***

3. Surgery:

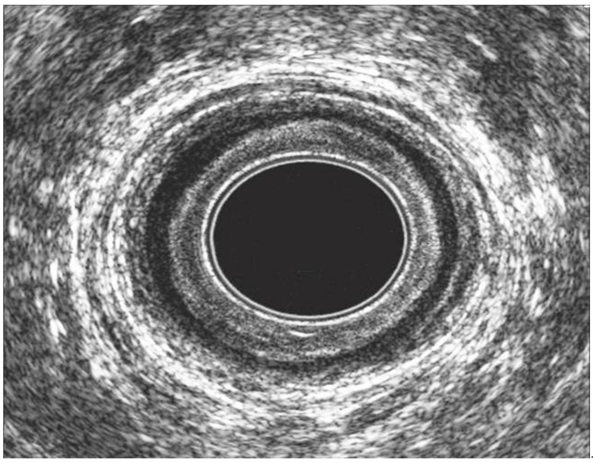
Fistula surgery is performed with epidural or general anesthesia. Patients are placed in the lithotomy position and examination under anesthesia is performed using a Hill–Ferguson retractor and a probe to search for the internal opening through the external opening. Once the internal opening was identified, the tract and laid open (fistulotomy) or excised (fistulectomy). The edges are not routinely marsupialized.

Anal incontinence is evaluated using the Jorge and Wexner scale (JW) and soiling is evaluated using a modification of the JW score ***(Jorge and Wexner, 1993).***

Risk factors for fecal incontinence included female patients with anterior transphincteric fistulas (women with intersphincteric anterior fistulas were included), female patients with obstetric injuries to the anal sphincters (those with episiotomies and no sphincter injury were not excluded), inflammatory bowel disease and patients who have undergone previous anal surgery and with major fecal incontinence according to the Jorge Wexner score ***(Garcés et al., 2012).***

Ultrasonographic anatomy of the anal canal:

In 1992, Tjandra et al. have performed elegant post-mortem and clinical studies and have identified the anatomic layers that correspond to the anal ultrasound images. ***Bartram*** confirmed these studies in ***2008*** **(*Tjandra et al., 1992; Bartram, 2008*).** On ultrasound, five hypoechoic and hyperechoic layers can be seen in the normal anal canal **(Fig.1).** The ultrasonographer must have a clear understanding of what each of these five layers represents anatomically ***(Santoro and Di Falco, 2006).***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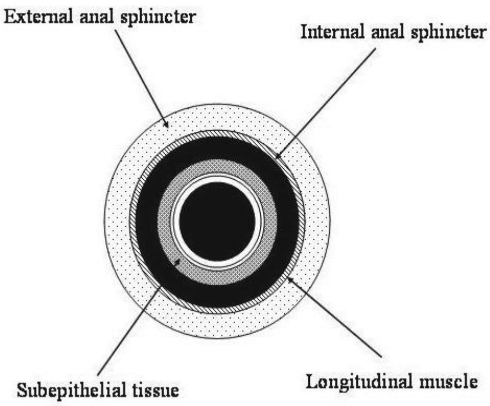

B

Fig. 1: Normal ultrasonographic five-layer structure of the mid-anal canal.
A Axial image obtained by 2050 transducer (B-K Medical) ***B*** Schematic representation ***(Santoro and Di Falco, 2010).***

- *The first hyperechoic layer,* from inner to outer, corresponds to the interface of the transducer with the anal mucosal surface.
- *The second layer* represents the subepithelial tissues and appears moderately reflective. The mucosa as well the level of dentate line is not visualized. The muscularis submucosae ani (MSA) can be sonographically identified in the upper part of the anal canal as a low reflective band.
- *The third hypoechoic layer* corresponds to the internal anal sphincter (IAS). The sphincter is not completely symmetric, either in thickness or termination. It can be traced superiorly into the circular muscle of the rectum, extending from the anorectal junction to approximately 1 cm below the dentate line. In older age groups, the IAS loses its uniform low echogenicity, which is characteristic of smooth muscle throughout the gut, to become more echogenic and inhomogeneous in texture ***(Starck et al., 2005)***.
- *The fourth hyperechoic layer* represents the longitudinal muscle (LM). It presents a wide variability in thickness and is not always distinctly visible along the entire anal canal. The LM appears moderately echogenic, which is surprising as it is mainly smooth muscle; however, an increased fibrous stroma may account for this. In the intersphincteric space the LM conjoins with striated muscle fibers from the levator ani, particularly the puboanalis, and a large fibroelastic element derived from the endopelvic fascia to form the "conjoined longitudinal layer" (CLL) **(Fig. 2)** ***(Shafik, 1976)***. Its fibroelastic component, permeating through the subcutaneous part of the external anal sphincter (EAS), terminates in the perianal skin. According to the "Integral Theory" proposed by ***Papa Petros***, the CLL creates the downward force for bladder neck closure during effort, and stretches open the outflow tract during micturition ***(Papa Petros, 2007)***.
- *The fifth mixed echogenic layer* corresponds to the EAS. The EAS is made up of voluntary muscle that encompasses the anal canal. It is described as having three parts: (1) the deep part is integral with the PR. Posteriorly there is some ligamentous attachment. Anteriorly some fibers are circular and some decussate into the deep transverse perinei; (2) the superficial part has a very broad attachment to the underside of the coccyx via the anococcygeal ligament. Anteriorly there is a division into circular fibers and a decussation to the superficial transverse perinei; (3) the subcutaneous part lies below the internal anal sphincter ***(Shafik, 1975)***.

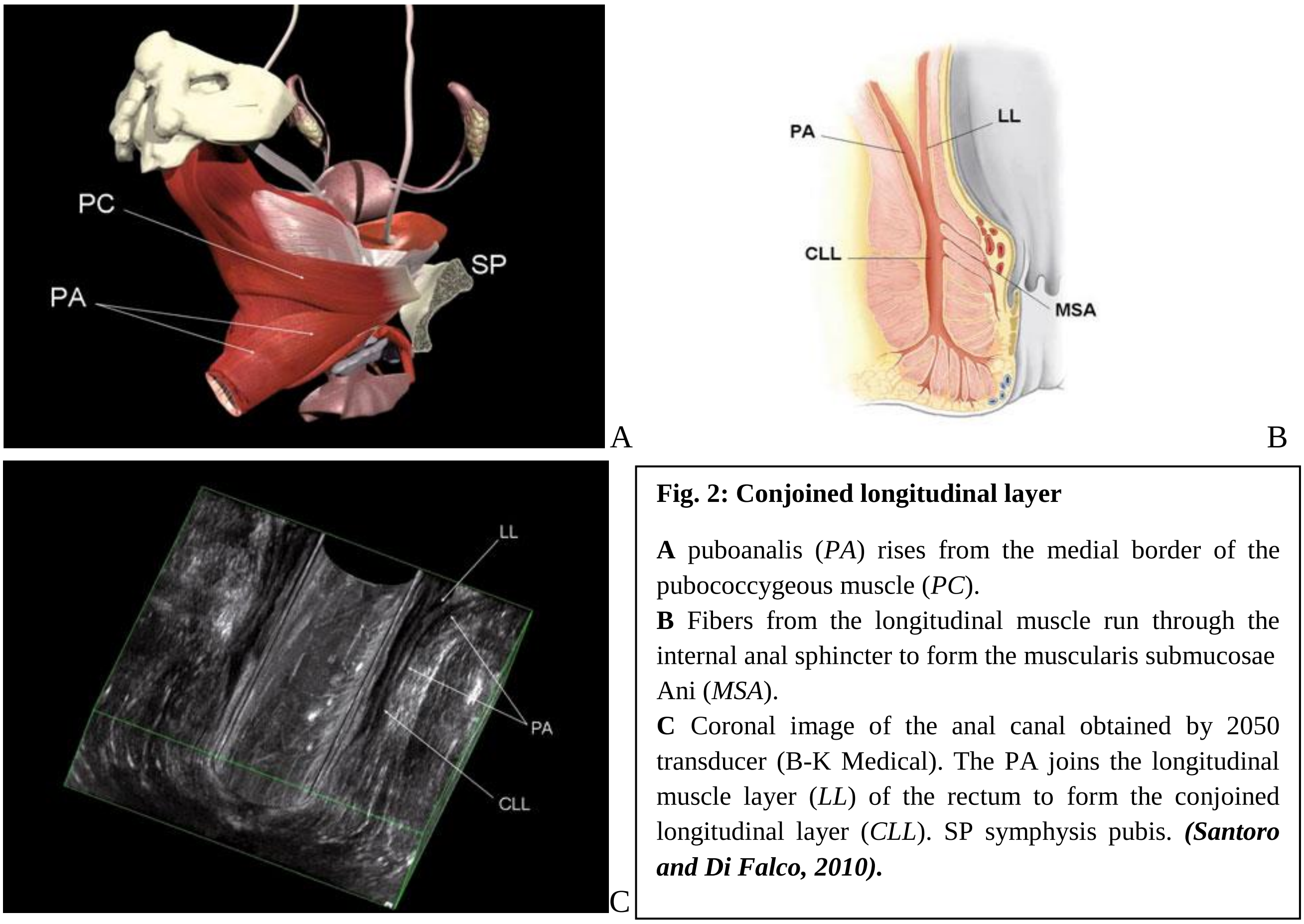

Fig. 2: Conjoined longitudinal layer

A puboanalis (*PA*) rises from the medial border of the pubococcygeous muscle (*PC*).
B Fibers from the longitudinal muscle run through the internal anal sphincter to form the muscularis submucosae Ani (*MSA*).
C Coronal image of the anal canal obtained by 2050 transducer (B-K Medical). The PA joins the longitudinal muscle layer (*LL*) of the rectum to form the conjoined longitudinal layer (*CLL*). SP symphysis pubis. ***(Santoro and Di Falco, 2010).***

Ultrasound imaging of the anal canal can be divided into three levels of assessment in the axial plane (upper, middle, and lower levels), referring to the following anatomical structures **(Figs. 3, 4)** ***(Santoro and Di Falco, 2006; Kumar and Scholefield, 2000; Hussain et al., 1996; Stoker et al., 2001)***:

- Upper level: the sling of the PR, the deep part of the EAS and the complete ring of IAS
- Middle level: the superficial part of the EAS (complete ring), the CLL, the IAS (complete ring), and the transverse perinei muscles
- Lower level: the subcutaneous part of the EAS.

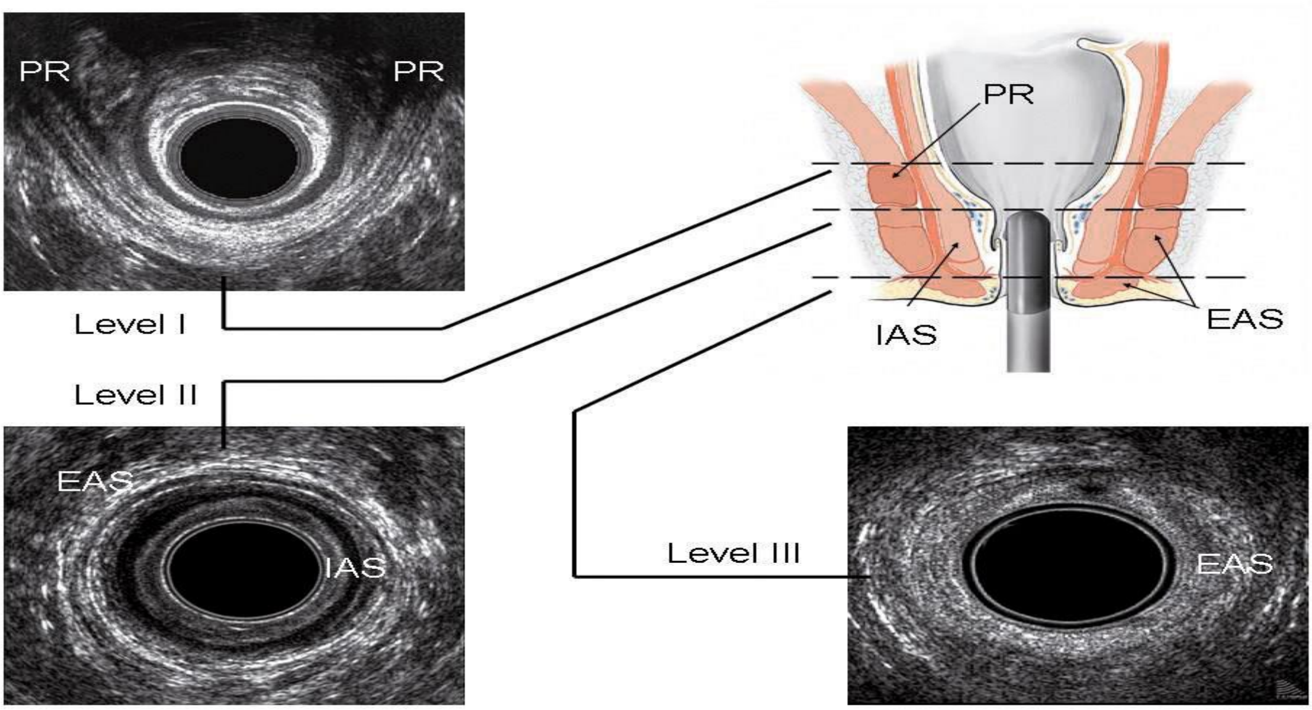

Fig. 3: Three levels of assessment of the anal canal in the axial plane. Right side of the image is left side of the patient.
EAS, external anal sphincter; *IAS*, internal anal sphincter; *PR*, puborectalis.
Scan obtained by 2050transducer (B-K Medical) ***(Santoro and Di Falco, 2010).***

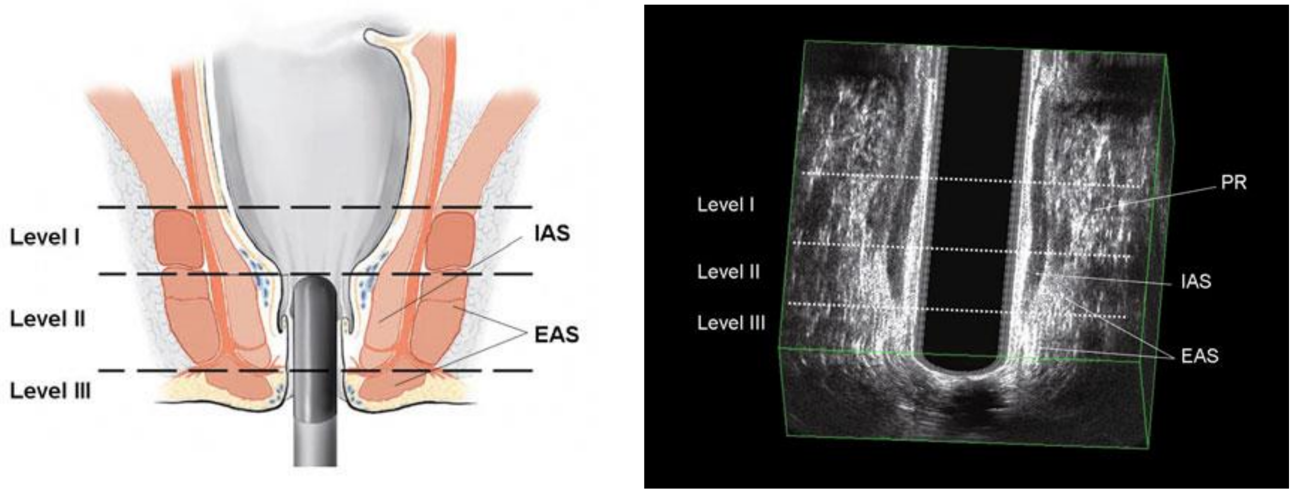

Fig. 4: Three levels of assessment of the anal canal. The internal sphincter ends at the level of the junction between the superficial (level II) and subcutaneous (level III) external sphincter.
A Schematic representation.**B** Coronal image obtained by 2050 transducer (B-K Medical).
EAS, external anal sphincter; *IAS*, internal anal sphincter; *PR*, puborectalis muscle***(Santoro and Di Falco,2010).***

The muscles of the lower and the upper part of the anal canal are different. The first ultrasonographic image recorded is normally the PR muscle and is labeled upper level. The PR slings the anal canal instead of completely surrounding it. At its upper end, the PR is attached to the funnel-shaped levator ani muscle and the levator ani anchors the sphincter complex to the inner side of the pelvis. The deep part of the EAS is similar in echogenicity to the PR and cannot be differentiated from it posteriorly. Anteriorly, the circular fibers of the deep part of the EAS are not recognizable in females, whereas in males thin arcs of muscle from the deeper part of the sphincter may be seen extending anteriorly.

Moving the probe a few millimeters in the distal direction will show an intact anterior EAS forming just below the superficial transverse perinei muscles, imaged at 11 o'clock and 1 o'clock **(Fig. 5).** This image is a mid-anal projection where the IAS, CLL, and superficial EAS all are identified. This image will be labeled middle level. In females, fibers between the transverse perinei fuse with the EAS, so that there is no plane of dissection between these two structures. In males a plane of fat persists between the transverse perinei and the EAS. EAUS is not able to precisely assess the perineal body because of the lack of clear limits. Also the proposed use of a finger introduced into the vagina as a landmark seems to be of poor benefit, altering its normal configuration due to the digital compression on the central perineum**.** At this level, the anococcygeal raphe is seen as a posterior hypoechoic triangle **(Fig. 5)** ***(Zetterstrom et al., 1998; Oberwalder et al., 2004)***.

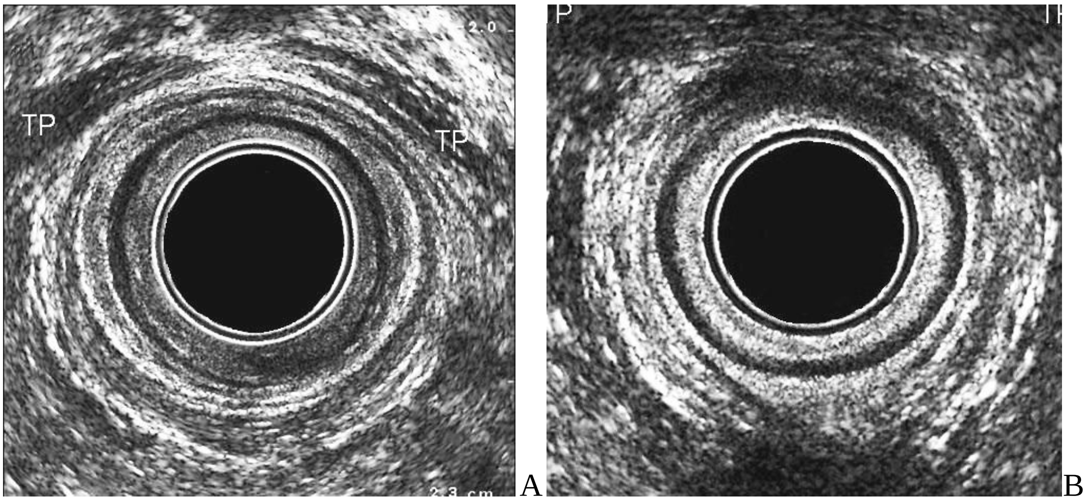

Fig. 5: Images of the transverse perinei muscles (*TP*) in the axial plane in male (a) and female (b).
The anococcygeal ligament is seen as a posterior hypoechoic triangle.
Scan obtained by2050 transducer (B-K Medical)***(Santoro and Di Falco,2010).***

When the probe is pulled further out, the image of the IAS will disappear and only the subepithelium and the subcutaneous segment of the LM + EAS will be seen. This last image will be labeled lower level **(Fig. 4).**

The anterior part of the EAS differs between genders, and anatomic studies have shown that this difference is already present in the fetus. In males, the EAS is symmetrical at all levels; in females, it is shorter anteriorly, and there is no evidence of an anterior ring high in the canal. In examining a female subject, the ultrasonographic differences between the natural gaps (hypoechoic areas with smooth, regular edges) and sphincter ruptures (mixed echogenicity, due to scarring, with irregular edges) occurring at the upper anterior part of the anal canal must be kept in mind. Three-dimensional longitudinal images are particularly useful to assess these anatomic characteristics of the EAS **(Fig. 6)** ***(Williams et al., 2000; Regadas et al., 2007; Bollard et al., 2002; Gold et al., 1999)***.

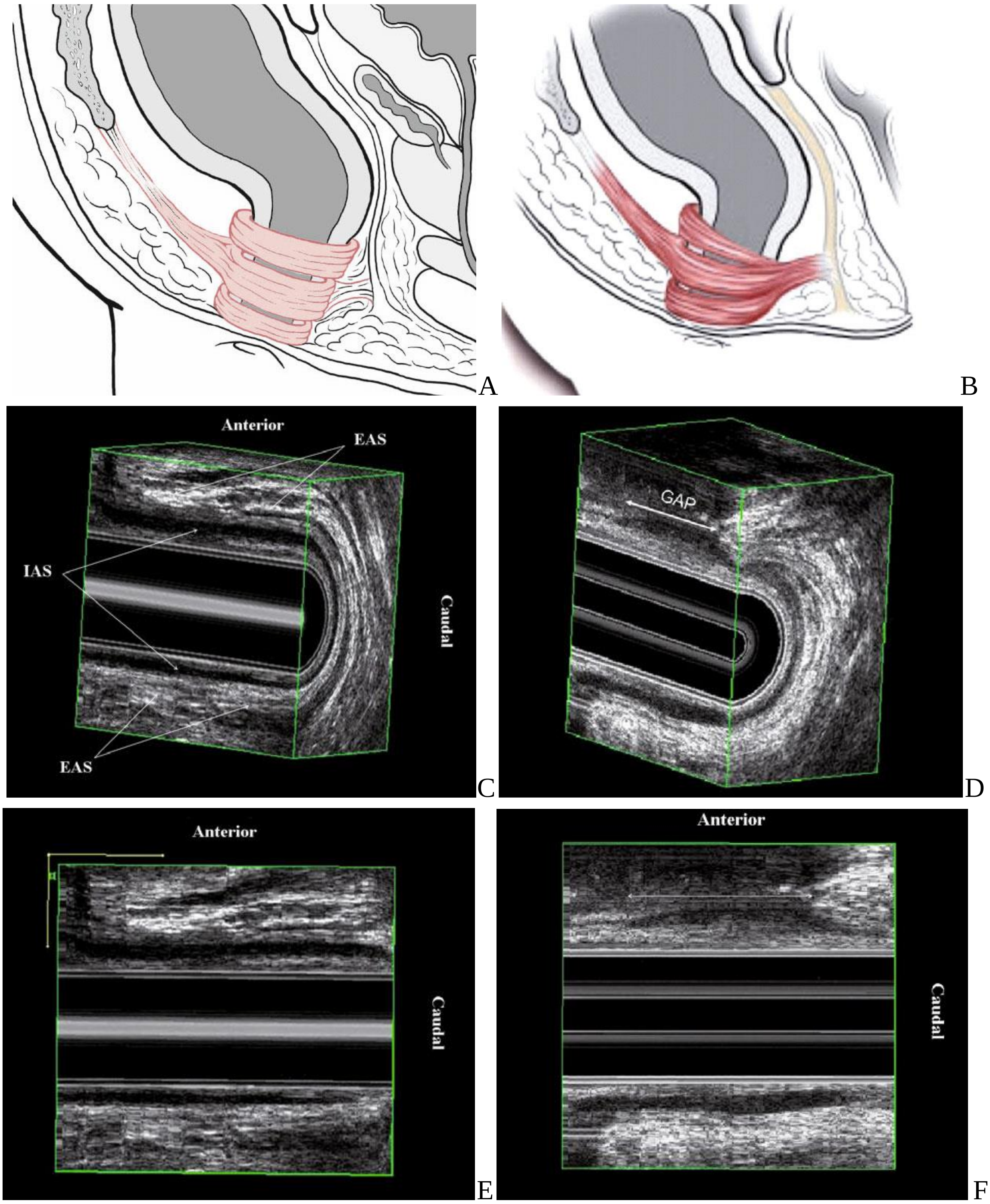

Fig. 6: The ventral part of the external sphincter differs between males (a, c, e**) and females (**b, d, and f**) (see text).**
a, **b** Schematic representations; **C–f** Three-dimensional endosonographic reconstructions in the longitudinal plane.
The distance between the anterior anorectal junction and the external sphincter is called the gap (*arrows*).
EAS, external anal sphincter; *IAS*, internal anal sphincter.
Scans obtained by 2050 transducer (B-K Medical)***(Santoro and Di Falco,2010).***

Anatomical differences between sexes:

In men the external sphincter is a more symmetric cylinder of less reflective muscle and so easier to delineate than in women. In women the puborectalis is a well-defined “U”-shaped structure with a striated texture and 6 mm in mean thickness ***(Frudinger et al. 2002)*** with a hypoechoic segment posteriorly representing the anococcygeal ligament. Anteriorly the perineal body seems amorphous and devoid of any structure, as it is mainly fibroelastic in content. The edges of the anterior aspect of the external sphincter slope downwards to meet in the midline **(Fig. 7)** in the mid canal, and it is not until this level that there is a complete cylinder of striated muscle in women.

On 3D studies ***(Williams et al. 2000)***, no significant difference in length between the sexes was found for the puborectalis (mean of 23.9 mm in men, 27.1in women), nor for the internal sphincter (mean34.4 mm, 33.2 mm, respectively), but there was a significant difference in the length of the external sphincter in all planes (anterior – 30.1:15.6; coronal– 31.6:19.5; posterior – 29.3:16.5, respectively). This confirms that the external sphincter is generally shorter; particularly anteriorly in women **(Fig. 8)**, which is supported by endoanal MR studies ***(Rociu et al. 2000).***

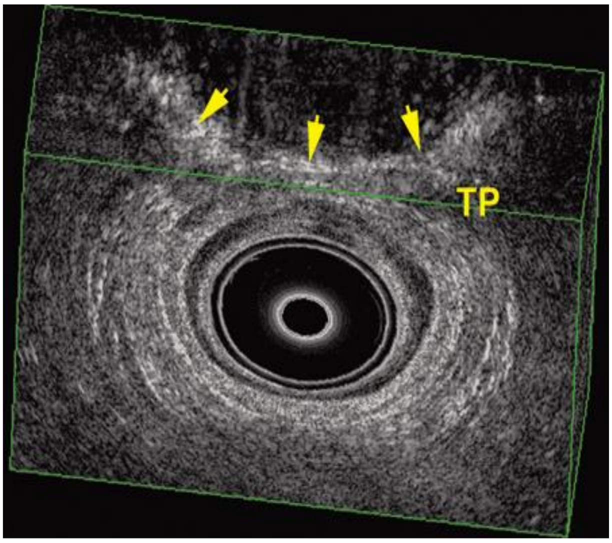

Fig.7.A 3D view in a woman of the external sphincters loping down to an intact anterior ring (*arrows*) with the transverse perinei (*TP*) fusing into this from each side ***(Santoro and Di Falco, 2010).***

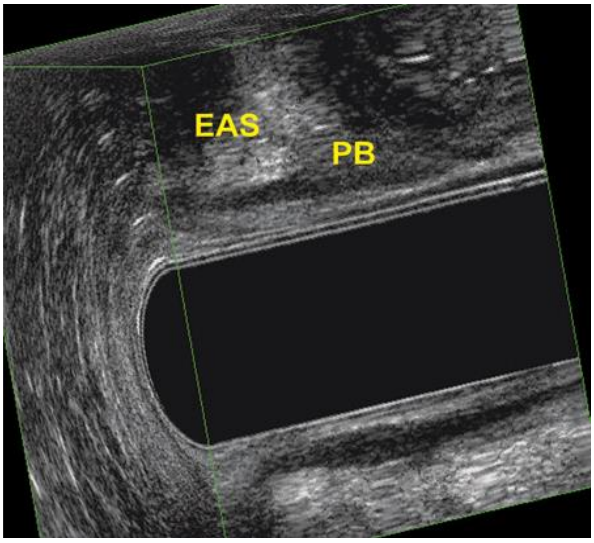

Fig.8.Sagittal view of the moderately reflective external sphincter (*EAS*) caudal to the low reflective perineal body (*PB*) showing how this is shorter anteriorly in the female ***(Santoro and Di Falco, 2010)***.

Effects of ageing:

The internal anal sphincter is not constant in thickness. In neonates it is very thin (< 1 mm), measuring1–2 mm in young adults, 2–3 mm in middle age and3–4 mm in the elderly. A slight increase in reflectivity of the sphincter as it becomes thicker is also secondary to increased connective tissue content. The external sphincter thins significantly in older nulliparous women, but the longitudinal layer, subepithelium or puborectalis was unchanged on endosonography ***(Frudinger et al. 2002)***, although the longitudinal layer has been shown to thin on endoanal MRI. MR provides a more definitive measurement as it does not rely on interface reflections for measurement of some layers, which may explain these discrepancies ***(Rociu et al. 2000)***.

Introduction:

Anorectal abscesses and fistulae are among the most frequently observed anorectal lesions. As anorectal abscesses frequently result in more or less complex and extensive fistulous tracts, the two pathologies should be regarded as the same condition. Abscesses and fistulas are two phases of the same disease. The abscess represents the acute inflammatory event while the fistula is representative of the chronic process. However, for practical and therapeutic reasons, they should be considered separately, except regarding etiology and spread of infection (***Eisenhammer, 1966***).

Etiology:

Perianal septic lesions may be the result of several etiologies. A distinction may be made between primary septic lesions of cryptoglandular origin and secondary septic lesions .Secondary septic lesions include Crohn's disease, pilonidal disease, hidradenitis suppurativa, tuberculosis, actinomycosis, trauma, fissures, carcinoma, radiation, chlamydia, local dermal processes, retrorectal tumors and diverticulitis. Primary septic lesions are the most common **(*Sainio and Husa, 1985*).**

Cryptoglandular theory suggests that increased back pressure due to occlusion of an anal gland duct, secondary to fecal material, foreign bodies or trauma, results in stasis and secondary infection with abscess formation in the intersphincteric space. The isolation of gut-specific organisms such as colonic aerobes and *Bacteroides fragilis* in the culture of pus tends to confirm the cryptoglandular origin of anal fistulas (***Eykyn and Grace, 1986***).

Only 10% of anal fistulas are due to a specific etiology; 90% of cases have a cryptoglandular origin. A previous history of abscesses may not be recorded in nearly one-third of the patients; in these cases, discharge is the first indication of trouble. A specific etiology of anal fistulas must be recognized as early as possible to avoid the risk of inadequate treatment ***(Abcarian, 1989)***.

Spread of Infection:

Infection may spread and seek the path of least resistance. It may extend downwards into the intersphincteric space resulting in a perianal abscess **(Fig. 9)**, upwards inside the longitudinal muscle layer within the gut walls causing an intermuscular abscess, or upwards outside the gut walls resulting in a supralevator abscess. It may spread across the external sphincter at any level, resulting in an ischiorectal abscess, which may also extend upwards or downwards **(Fig. 10).** Furthermore, circumferential spread is possible at any level within the intersphincteric space, the ischiorectal space, or the supralevator space. It may extend from one ischiorectal fossa to the contralateral one via the intersphincteric space of Courtney or deep post-anal space, resulting in a so-called horseshoe abscess (***Hamilton, 1975***).

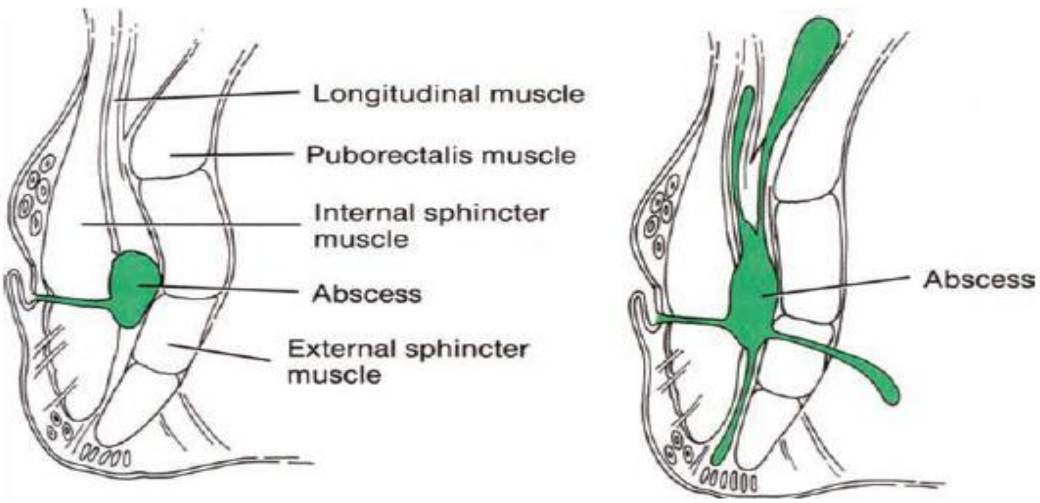

Fig.9: Pathways of anorectal infection in perianal spaces *(Gordon, 2001)*.