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The Ilio-Coccygeus Muscle (ICM) Does it have an Enabling Role in Urination?

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Abstract

An analysis of the literature has allowed for a redefinition of the anatomy of the ilio-coccygeus muscle (ICM) its insertions and its trajectory, the direction of its fibers and its relation to the base of the bladder. Static MRI studies have revealed its V-shaped appearance, while dynamic MRI has been used to visualize its concave contraction into a dome-shape that provides support to the levator plate, raising the base of the bladder. Histological studies have shown that the percentage of type I muscle fibers is 66% to 69%, which is comparable to the type I fiber content of the pubovisceral muscle (PVM), thus reflecting both its postural role as well as functions based on frequent voluntary contractions. Together, these data suggest an active role for the ICM which, upon urination, allows for voluntary hardening of the levator plate. The abdominal pressure from bearing down hence enables urinary draining by compressing the bladder on a hard surface. The physiological function of the ICM is therefore not only postural, but also to enable urination. From a therapeutic perspective, a multicentric study has shown that, by reinforcing the action of the ICM, use of a Diveen intrauterine device improved dysuria.

Keywords: Anatomy; Dysuria; Levator ani muscle; Ilio-coccygeus muscle; Pelvis; Physiology

Introduction

The levator ani muscle (LAM) is the main muscle of the pelvic floor, and it plays a major role in providing pelvic support. It is generally considered to be comprised of two parts: the pubovisceral muscle (PVM), which is anteromedial; and the ilio-coccygeus muscle (ICM) which is posterolateral [1]. For some authors it comprises three parts, as they further distinguish the puborectal muscle (PRM) from the PVM and the ICM [2]. The conventional function assigned to the ICM is a static action (i.e. posture). The recent hypothesis of a difference in elasticity between the vertical vaginal wall (VVW) below the urethra and the horizontal segment of the anterior vaginal wall below the bladder has led to the concept of absorption of abdominal pressure under the bladder upon bearing down [3,4]. According to this hypothesis, the difference in elasticity results in several events that lead to a passive mechanical adaptation of the pelvis upon bearing down [5]. By reversing this hypothesis one can, by contrast, deduce that upon urination there is a need to increase the rigidity under the bladder to enable urination. This enabling function could be linked with the action of the ICM. This article is hence a revision of the anatomical data and MRI studies in order to verify their compatibility with the assumed function of the ICM enabling emptying of the bladder upon bearing down during urination.

Anatomical Description of the ICM

The ICM is the lateral and the least thick part of the LAM. It inserts laterally from the back to the front on the ischial spine and on the pelvic bone at the level of the linea terminalis and on the posterior ligament of the subpubic canal or the Gunsee ligament a thickening of the obturator membrane (Figure 1) [6].

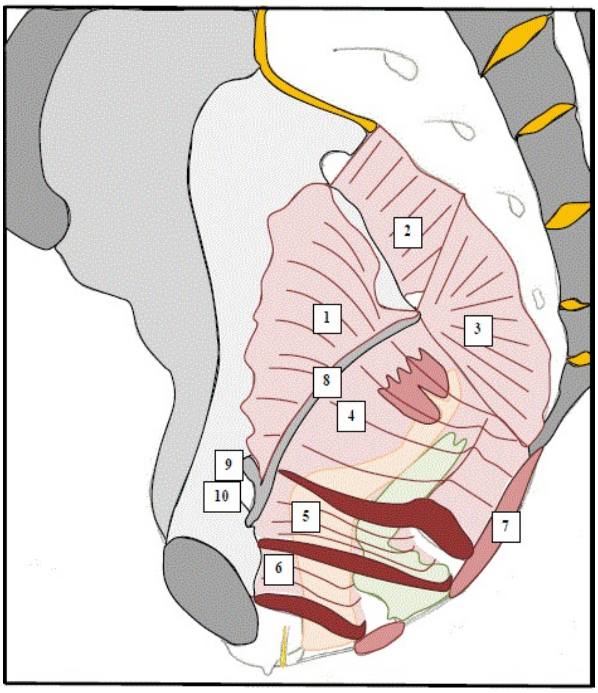

Figure 1: Anatomy of the ilio-coccygeus muscle. A: Muscles of the pelvis. 1: Internal obturator muscle. 2: Piriformis muscle. 3: Coccygeal muscle. 4: Ilio-coccygeus muscle (ICM). 5: Puborectalis muscle (PRM). 6: Pubovisceral muscle (PVM). B: Means of ICM attachment. 7: Anococcygeall raphe. 8: Arcus tendineus Levator Ani (ATLA). 9: Ligament of Gunsee. 10: Obturator foramen.

The muscle fibers run diagonally in the rear and inner sections and they end on a medial raphe or anococcygeal ligament. These fibers constitute the levator plate onto which the pelvic organs place pressure upon bearing down. The levator plate is normally horizontal and supports the rectum and two thirds of the vagina. On its upper side it is covered by the endopelvic fascia which thickens at the level of the bony insertion that forms the Arcus tendineus levator ani (ATLA) [7]. Thus by means of the fascia, the ICM is directly in contact with the lower-external side of the bladder (Figure 2).

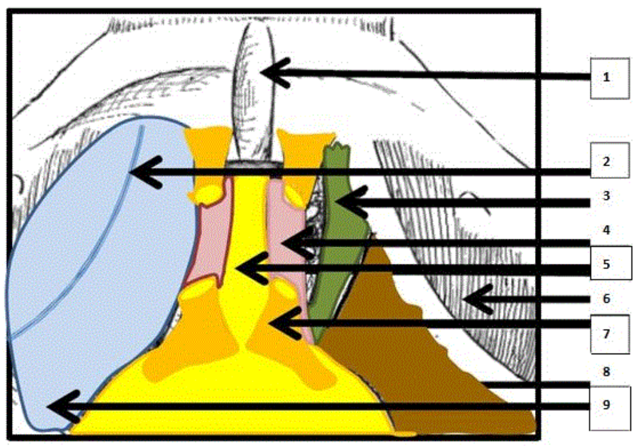

Figure 2: Anatomical relationships between the bladder and the ilio-coccygeus muscle. 1: Pubic symphysis. 2: ATLA. 3: PVM. 4: Vagina. 5: Urethra. 6: Internal obturator muscle. 7: Pillars of the bladder (sectioned). 8: ICM. 9: Endopelvic fascia.

Normal and Pathological Presentation of the LAM by MRI

Diffusion tensor MRI imaging allows the orientation of the muscle fibers to be determined and specially the orientation of each fiber of the LAM relative to a horizontal direction going through the lower edge of the pubis on a sagittal section to be measured [8]. The average angle made by the fibers of the PVM, the PRM, and the ICM and the horizontal axis were determined to be: 41+/-8°, −19+/-10°, and 33+/-8,8°, respectively with a difference of 60° between the PVM and the PRM. These angles reflect different modes of action of the various muscles. Indeed, the orientation in which muscle fibers undergo maximal shortening corresponds with the direction of their mode of action.

Technical innovations in regard to MRI allowed to better understand the morphology of the LAM [9]. MRI with a superconducting magnet was used to take T2 weighted images in two dimensions in axial, sagittal and coronal sections of the pelvic floor in subjects in a supine position. The most commonly used settings use slice thicknesses of 4 mm with a gap of 1 mm. This allows for generation of three dimensional color reconstruction of the LAM, while also allowing for dynamic analysis of its function.

An axial section is the section of choice for visualizing the PVM. This shows its insertions at the level of the pubis and medially relative to the PRM, the intersphincteric ending of the PRM and on the lateral walls of the vagina for the PVM. The ring of the PRM behind the rectum and the origin of the ICM on the ATLA can also be seen. A coronal section is ideal for visualizing the ICM. It exhibits a typical V-shape, with the ICM originating at the ATLA. This shape differs from the macroscopic description provided by the operator or its appearance upon dissection of anatomical specimens. Thus, the ICM is typically shaped more like a funnel than an arch.

A sagittal section allows the levator plate formed by the ICM to be seen.

The orientation of the fibers of the PVM can also be seen with insertion of the puboperinealis muscle on the perineal body and that of the puboanal muscle at the level of external sphincter of the anus. Lastly the orientation of the fibers of the PRM can be seen and its ring-like layout around the rectum.

The dynamic nature of the LAM has also been investigated by MRI [10]. Upon retention there is an increase in the convexity toward the top of the ICM and a convergence of the PVM. On the other hand upon bearing down the PRM bundles separate and the ICM becomes concave. The base of the bladder is lifted upward and forward during voluntary pelvic contractions, while it descends when bearing down. This upward push of the bladder translates into an opening of the posterior urethrovesical angle relative to the resting position; changing from 110°+/-20° to 150° [11].

Histology and Functional Appearance of the Levator Ani Muscle (LAM)

The LAM is a striated muscle. Dissections performed on 25 anatomical samples (10 fetuses and 15 adults) [12] demonstrate that the LAM is comprised of two distinct components: a lateral part composed of a single layer of muscle made up mainly of type I fibers (for slow contraction) and to lesser extent also type 2 fibers (for fast contraction); as well as a medial part. The latter is thought to be comprised of two layers of muscle separated by connective tissue containing neurovascular elements: a deep layer of muscle with striated muscle cells (voluntary action) and a superficial layer comprised of smooth muscle cells. With age and a lack of estrogen the number of striated muscle cells and the diameter of the type 1 and type 2 fibers decrease [13]. These characteristics are also found in patients who have urinary incontinence, and they constitute a risk factor for recurrence following surgery for the incontinence [14].

From a functional point of view, it should be pointed out that, like most postural muscles, the levator ani muscle is essentially composed of type I fibers [15]. Type I fibers are slow-twitch fibers and their functioning relies mainly on aerobic metabolism. Their main characteristic is to be able to develop prolonged tonic contractions.

This separates them from type II fibers. These mainly function by anaerobic metabolism, and they undergo rapid contractions, while lacking in endurance.

The high proportion of type I fibers is one of the characteristics of the levator ani muscle in humans, and this can probably be explained by the frequent upright position of humans that places constant pressure on this muscle as a result of it bearing much of the weight of the pelvic organs. Indeed, with four-legged animals such as mice and rats, the ICM is essentially composed of type II fibers arranged in acraniocaudal orientation, as its role in providing support for the pelvic organs appears to be minor [16]. The proportion of type I fibers varies for the different muscles that comprise the LAM. Thus, for the PVM this proportion ranges from 66% to 82%. The fibers of the PRM are thought to be about 90% type I. Lastly, the fibers of the ICM are thought to be 68% to 69 % type I [17,18].

This suggests that the function of the levator ani muscle is to exert a permanent tonicity in an upright position so as to support the weight of the pelvic organs. As the level of type I fibers in the PVM is only 66% to 82% (as opposed to 90% for the PRM), the PVM also undergoes voluntary contractions. These voluntary contractions increase the tonicity required to account for a sudden increase in abdominal pressure, and to actively block leakage of urine. Similar to the PVM, the ICM has a high level of type I fibers, which suggests that it also undergoes frequent voluntary contractions, and hence has more than just a postural role.

Function of the ICM

The function of the ICM is typically a static action (posture), and its weakening linked to that of the LAM results in sagging of the levator plate and widening of the urogenital diaphragm, thereby enabling the occurrence of pelvic prolapse [19].

The collection of data above indicates that the ICM in fact has an active role, with frequent voluntary contractions. It has a close anatomical relation with the base of the bladder.

Anatomically, its upper end inserts into an immobile sector of bone, while the lower end inserts into the mobile and deformable anococcygeal raphe. Upon contraction, the coccygeal raphe is hence pulled upward, which pushes the tailbone forward (Figure 3). The MRI studies [20] performed with women sitting in an upright position revealed movement of the coccyx in a ventral and cranial direction, with a ventral displacement of 10.8 mm.

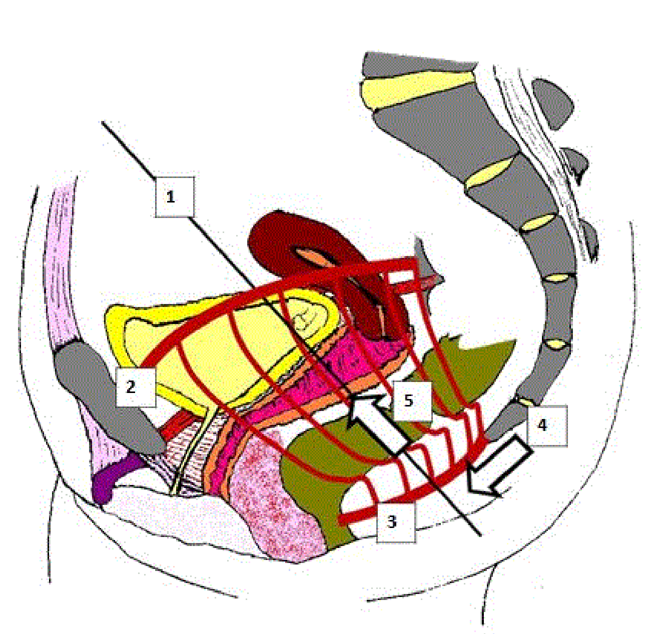

Figure 3: Sagittal sections: engagement of the ilio-coccygeus muscle. 1: Medial axis of the muscle fibers of the ICM. 2: Immobile end of the ICM: ATLA. 3: Mobile end of the ICM: Anococcygeal raphe. 4: Forward traction and antepulsion of the coccyx. 5: Upward traction of the anococcygeal raphe against components of the digestive tract.

A consequence of the upward and forward pull of the anococcygeal raphe could be a closing of the anorectal angle, thereby reinforcing anal continence. An investigation of the literature did not reveal any objective studies that would allow for confirmation or rebuttal of the hypothesis of an active role for the ICM in anal continence. As is the case for all striated muscles, contraction of the ICM shortens it and increases its thickness.

Thus, with voluntary pelvic contractions (i.e. voluntary bearing down that accompanies urination), MRI studies have shown that the base of the bladder is lifted upward (Figure 4), with an increase in the upward concavity and a decrease in the hiatus by a convergence of the PVMs. Hence, thickening of the ICM due its contraction stiffens the levator plate under the bladder. This thickening of the ICM during the contraction leads to it assuming a dome-like shape (i.e. an upward concavity) and a decrease in the hiatus by convergence of the PVMs.

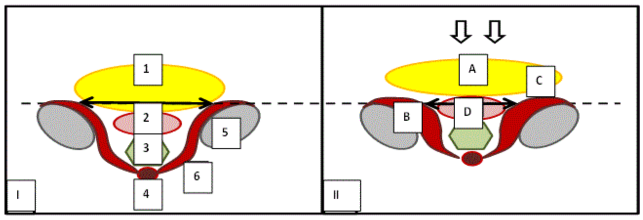

Figure 4: Frontal section: engagement of the ICM ,I: At rest. 1: Bladder. 2: Vagina. 3: Rectum. 4: Anococcygeal raphe. 5: Bony structure, linea terminalis. 6: ICM. II: During contraction of the ICM. A: Elevation of the bladder. B: Concave appearance of the ICM. C: Increase in the thickness of the ICM. D: Decrease in the cleft.

Hence, the pressure exerted by abdominal bearing down during urination allows for compression of the bladder on a harder surface, with a narrower hiatus, and hence increased efficacy.

It should be noted that the two functions of improving anal continence and enabling of micturition by the bladder occur simultaneously, which in everyday life translates into defecation during micturitional bearing down.

Can the Action of the ICM be Strengthened to Treat Dysuria?

This issue was raised by the results of the multicentric study [20] evaluating the efficacy of the Diveen intravaginal device for treating stress urinary incontinence, with the aim of verifying the hypothesis that there is a physiological difference in vaginal and pelvic elasticity on each side of the vaginal cap [21,22]. This clinical evaluation by a multicentric group involved doctors who were engaged in different health sectors (e.g. public hospitals versus private practice) and who had various specializations (e.g. urologists, obstetric-gynecologists, reanimators). In order to ensure maximal objectivity, the identity of the sponsor was not revealed to any of the investigators involved in the study. One of the items studied was the influence of the Diveen intravaginal device on dysuria. The aim of this part of the study was to ensure that an intravaginal device did not result in dysuria, which hinders urination. The outcomes for this part of the study have in fact shown that the opposite is the case. Thus, use of a Diveen intravaginal device tended to lead to an improvement of the dysuria. Fifty-five patients were enrolled and analyzed in this study (26 controls and 29 treated). The USP dysuria subscore (/10) was slightly lower for the treatment group [1.2 ± 1.7 (0-8)] relative to the untreated group [0.8 ± 1.3 (0-4)], with p=0.44.

Thus, pending validation of the results from other studies investigating dysuria with a larger and more significant cohort, one can assume at this stage that female dysuria may be specifically targeted by use of a Diveen intravaginal device. Strengthening of the ICM by selective reeducation may also be a consideration, not only in women but also in men.

Conclusion

The same way that there are two sides to the urethrovesical equilibrium, there are two different groups of muscles in the LAM with two different muscular functions. These functions comprise adaption by the PVM to bearing down so as to block urinary leakage, and the ICM assisting with urination. Indeed, the main function of the ICM very much appears to be its role in enabling urination and in increasing anal continence.

These two functions are unlikely to be gender-specific, and similar studies -using MRI in particular- of male subjects ought to be undertaken to confirm this. If this role of enabling urination also clearly takes place in males, it seems likely that absorption of pressure under the bladder that is exerted during abdominal bearing down is a process that also occurs in males. Female dysuria can be improved by use of a Diveen intravaginal device. Similarly, research protocols should be devised to determine whether reeducation or strengthening of the ICM by electrostimulation may improve dysuria in both sexes.

Conflict of Interest

Filings of industrial patents and partnership with the B. Braun Medical SAS laboratory, 204 Avenue du Maréchal JUIN, BP 331, 92107 BOULOGNE CEDEX for the purpose of development of a preventive intravaginal device for female urinary incontinence. No participation in the 75NC007 multicentric trial.

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