Review

Fascial continuity of the pelvic floor with the abdominal and lumbar region

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Introduction: The connection between the pelvic floor, abdomen and lower back is clinically recognized but the anatomical basis of this link requires further clarification. The purpose of this work was to review the literature on pelvic fasciae, in order to provide a description of their continuity with the fasciae of abdominal muscles and lower back. *Materials and Methods:* A search of the literature was conducted on the PubMed database, using keywords that contain the term "fascia" in relation to different anatomical regions. The list of articles found was reviewed for relevant publications and a total amount of 41 scientific works was considered suitable for our investigation. For further research we used international reference texts on Anatomy. *Discussion:* The review of the literature confirms our idea of a fascial continuity and describes its development, at several levels: 1) superficial fascia; 2) superficial layer of the deep fascia; 3) deep layer of the deep perineal fascia; this layer can be divided into two separate layers by the levator ani muscle. *Conclusion:* Anatomically, the continuity in the fasciae of the abdominal wall, pelvic floor and lumbar region is plausible. A "new" theory of fascial anatomical continuity could have implications in the understanding of the clinical presentation of pelvic pain, the comprehension of the anatomical link between abdominal-lumbar disorders and pelvic floor, and in the treatment of chronic pain conditions, leading to an enhancement in current anatomical knowledge and therapies.

Keywords: Colles fascia; Urogenital diaphragm; Pelvic floor; Integral theory; Fascia.

INTRODUCTION

The pelvic floor is a well-defined anatomical and functional region including organs[1] and tissues located between the pelvic inlet and the perineum; many of these structures pass through the perineum and develop a mutual dynamic and functional integration. On the basis of this integration, a new idea has been promoted in literature, namely the concept that the clinical presentation of a variety of musculoskeletal disorders may be explained by "fascial communication", which may play a leading role in the transmission of pain.[1] It is therefore plausible to describe the fascia as a source of proprioception and nociception.[2]

However, a general anatomical connection between the fasciae of the pelvic floor, the abdomen and the lower back has not been described nor assumedyetin literature: such concept could lead to the establishment of a "theory of a whole-body fascial linkage", that could explain the presence of referred pain as transmitted through a fascial layer.

The purpose of this study was to review the literature in order to obtain more insight into the status quo of fascial anatomy in the abdominal, lumbar and pelvic regions and to prepare the ground for a new anatomical pattern.

MATERIALS AND METHODS

A search of the literature was conducted using the PubMed database in November 2015. In order to find suitable articles for the literature review, the following keywords were used: "fascia", "pelvic floor", "endopelvic fascia", "perineal membrane", "anatomy", "terminologia anatomica", "nomenclature", "abdominal wall", "retroperitoneal space", "human abdominal fascia", "Colles fascia", "urogenital diaphragm", "pelvic floor dysfunction", "pelvic organ prolapse", "arcus tendineus fasciae pelvis", "parietal presacral fascia", "rectosacral fascia", "Waldeyer's fascia", "membranous layer", "Scarpa's fascia", "transversalis fascia" and "superficial fascia". Search terms were used individually or in combination. Reference lists of identified articles were also reviewed for relevant publications and 41 scientific studies were considered the most related to our work. In addition, the classic reference texts on Anatomy were consulted: Gray's Anatomy, Atlas of Human Anatomy (Netter), Topographic Anatomy Textbook (Testut).

RESULTS

According to Stoker,[9] the pelvic floor constitutes four principal layers: endopelvic fascia, the muscular pelvic diaphragm (commonly referred to as levator plate), the perineal membrane (urogenital diaphragm) and the superficial transverse perineii. The anorectum and pelvic floor have multiple interconnections by fascia and ligaments as well as multiple indirect connections to the bony pelvis. According to Park *et al*.,[10] further, more superficial connections exist. To demonstrate this continuity, Park *et al*.[10] injected five fresh cadavers with contrast material in the space between Dartos and Buck fasciae of the penis, showing that the contrast material filling the scrotal cavity extended posteriorly in the perineum, remained far below the urogenital diaphragm, and reached superiorly to the potential space along Scarpa fascia in all cadavers. During cadaveric dissection, the ink-stained spaces were confined by the fascial planes involving Colles, Buck, Dartos, and Scarpa fasciae. All these fasciae are superficial fascia, placed in the middle of the hypodermis. Colles fascia is in continuity posteriorly with the corrugator cutis ani, a layer of muscular fibers around the anus, which radiates from the orifice. Medially the fibers fade off into the submucous tissue, while laterally they blend with the true skin. By its contraction it raises the skin into ridges around the margin of the anus.[8] This muscle is the homolog of the panniculus carnosus found in mammals, and in humans, corresponds to the superficial fascia.[2]

Martin[11] also described a specific attachment of this subcutaneous layer (or superficial fascia) with the deep fascia, defining some pocket-like diverticulae. The lateral pocket continues into the superficial perineal pouch. The medial pocket, together with the intermediate, occupies the scrotum or labium majus. The intermediate pocket is associated with the spermatic cord or the round ligament of the uterus

and blends with their coverings posteriorly. However, in the male it terminates just above the testes.

A second, deeper continuity among the abdominal, pelvic and lumbar fasciae could be recognized and is realized by the Gallaudet fascia (or deep perineal fascia, or superficial investing fascia of the perineum). Indeed this fascia surrounds the bulbospongiosus, ischiocavernosus and superficial transverse perineal muscles. This fascia is attached laterally to the ischiopubic rami and fused anteriorly with the suspensory ligament of the penis or clitoris. According to Gray's anatomy,[8] it is continuous anteriorly with the deep investing fascia of the abdominal wall muscles (in particular with the fascia of the external oblique muscle), and in males, it is continuous with Buck's fascia. Superficial transverse perineal muscle continues with the external anal sphincter[12] and with the anococcygeal ligament. According to Kinugasa *et al*.,[13] the anococcygeal ligament is divided into two layers: a thick ventral layer, rich in thin vessels and extending from the presacral fascia to the conjoint longitudinal layer of the anal canal, and a thin dorsal layer extending between the coccyx and external anal sphincter. A recent paper[14] also confirmed that the anococcygeal ligament (ACL) is formed by two distinct structures: a superficial fibrous band originating from the myosepta of the external anal sphincter and running upwards to the coccyx (the superficial ACL); and a deep fibrous band originating from the periosteum of the coccyx, merging with the thick presacral fascia and attaching to the superior end of the EAS (the deep ACL). From the coccyx and sacral bone the gluteus maximus with its fascia origins is in continuity with the posterior layer of the thoracolumbar fascia.[15]

Finally, a third, deeper fascial continuity could be recognized. Gray (1918) described the urogenital diaphragm as consisting of two dense membranous laminæ which are united along their posterior borders, but are separated in front by intervening structures. The superficial of these two layers, the inferior fascia of the urogenital diaphragm, is triangular in shape, and about 4 cm in depth. Its apex is directed forward, and is separated from the arcuate pubic ligament by an oval opening for the transmission of the deep dorsal vein of the penis. Currently, insights indicate the presence of a musculofascial unilayer structure, while questioning the existence of superior fascia and deep transverse perinei.[9] As a more appropriate alternative, the term perineal membrane is suggested. Stein & DeLancey,[16] examining serial cross-sections, revealed that the perineal membrane is a complex structure that is only one component of a larger interconnected support apparatus. In particular, this study revealed that the perineal membrane has two distinct parts; a dorsal portion and a ventral portion and that the levator ani muscle is intimately connected with this structure. The perineal membrane is posteriorly inserted into the perineal body (also named the central perineal tendon) which is a site of attachment of many structures and therefore has an important function in the complex interaction of the pelvic floor muscles. In the central perineal tendon six muscles converge and are attached: the sphincter ani externus, the bulbocavernosus, the two transversi perinæi superficiales, and the anterior fibers of the levator ani. In actual fact, the central perineal tendon could be considered a point of fusion among the various layers forming the pelvic floor, in a similar manner to the linea alba of the muscular-fascial layer of the abdomen. Gray's Anatomy[8] pointed out that "central nucleus of the perineum" is an inappropriate term, as it is neither central nor tendinous. It is composed of connective tissue, elastin, and smooth muscle, distributed irregularly within the body but becoming almost horizontal toward the rectovaginal septum. The attachment of the levator ani muscles to the perineal membrane and perineal body means that disruption to the midline connection between the perineal membranes of each side though the perineal body allows loss of perineal body support and also lateral displacement of the perineal membrane.[16]

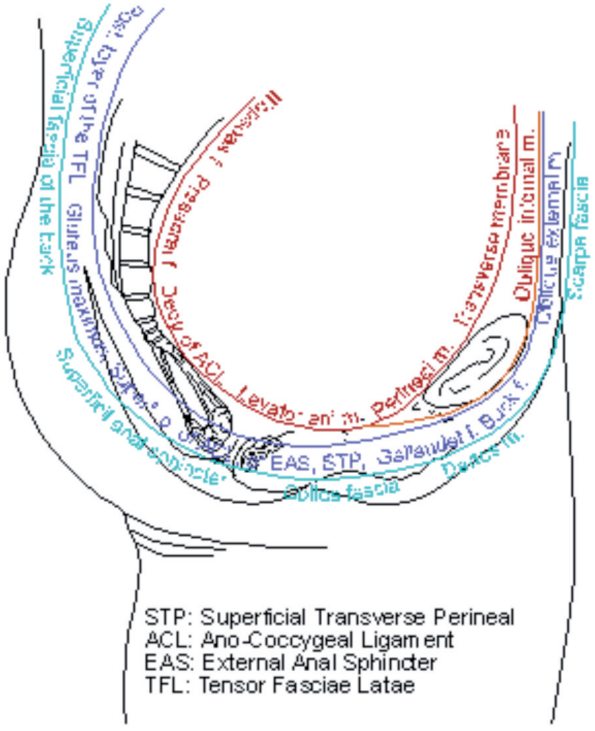

Figure 1. – Scheme of the fascial continuity among the muscular-fascial layers of the pelvic floor, abdomen and back.

According with DeLancey[17] the perineal membrane is a single sheet of fascia extending between the pubic arch and the ischiopubic rami and denoting a boundary between superficial and deep perineal spaces.

Posteriorly, the perineal membrane is connected with the presacral fascia through the deep fibrous band of the anococcygeal ligament (ACL). Indeed this band originates from the periosteum of the coccyx, merging with the thick presacral fascia, and attached to the superior end of the external anal sphincter.[14] Whilst the superficial ACL is composed of very tortuous elastic fibers, with a fine elastic fiber mesh, the deep ACL is composed of almost straight collagen and elastic fibers, intermingled with the coccygeal periosteum. Consequently, the deep component can play an important role, in association with contraction of the longitudinal anal muscle and with the thick presacral fascia, in maintaining a suitable positioning of the anorectum to the coccyx. However, their relative lack of smooth muscles compared with rich elastic fibers indicates that both ACLs may become permanently overextended under conditions of long-term mechanical stress.[14]

DISCUSSION

A careful and thorough analysis of literature supports the idea of a fascial continuity between abdomen, pelvic and the lumbar region.Our literature review and a comparison of anatomical texts allowed us to describe this fascial continuity as follows:

1) superficial layer: in an anteroposterior sequence, it is formed by Scarpa's fascia → Colles' fascia → (sphincter ani) → superficial fascia.

2) superficial layer of the deep fascia: in anteroposterior sequence, formed by the aponeurosis of the external

oblique muscle → (ischiocavenous and bulbospongiosus muscles) in connection with the Gallaudet and Buck's fascia, up to the fascia lata of the thigh → superficial transverse perineal muscle and Gallaudet fascia central tendon of perineum → superficial portion of the external anal sphincter → superficial portion of the anococcygeal ligament → (gluteus maximus) posterior layer of the thoracolumbar fascia.

3) deep layer of the deep fascia: in anteroposterior sequence, formed by the internal oblique and transverse aponeurosis, that blend into each other at the level of pubic symphysis, forming the urogenital diaphragm → central tendon of perineum → (levator ani muscle) → deep portion of the anococcygeal ligament presacral fascia → iliac fascia of the iliopsoas muscle. This deep fascial layer can be divided again into two levels, assuming the levator ani muscle as an ideal boundary line stretching from the urogenital triangle anteriorly to the deep transverse perineal muscle posteriorly. Therefore we can describe: a superficial layer – above the levator ani – formed by the superior band of the pelvic diaphragm that bends posteriorly, through the tendinous arch of pelvic fascia, with the aponeurosis of the internal obturator muscle; and a deep layer including the lower band of the pelvic diaphragm which merges anteriorly with the aponeurosis of the internal oblique abdominal muscle.

CONCLUSION

There is no description in literature of a fascial continuity between abdominal wall, pelvis and lumbar wall; though the topographic anatomy of these anatomical regions is well known. An overview of these fascial structures has not been well established. Our study, through a scientific review and a comparison of anatomy texts, demonstrates that a "fascial continuum" actually exists and such knowledge could improve the understanding of referred pain pathophysiology and mechanisms. However, a deeper and more detailed anatomical study is essential for the validation of this notion, and forms the focus of our future research.

Recently reports have demonstrated that the deep fasciae are well innervated[18,19,20] and capable of transmitting mechanical forces from a distance[21,22]. This concept of a fascial anatomical continuity may have important implications for the understanding of the clinical presentation and treatment of pelvic pain, such as the case of pelvic pain resulting from abdominal (eg. caesarean section, abdominal surgery) or lumbar injuries. Conversely, lower back symptoms might find their origin and explanation in pelvic floor disorders. This new concept could improve the treatment of chronic pain and could lead to an important enhancement of current anatomical knowledge and therapies.

DISCLOSURE STATEMENT

The authors declare that they have no conflict of interest.

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The pelvic floor is a well-recognised anatomical and functional region with its muscles, ligaments and bony structures clearly identified and labeled. As there was a lack of understanding of the complexity of the pelvic fascia and its multilayer continuity throughout the abdomino-lumbar regions, it now became logically identified by Dr Carla Stecco's team. The concept of fascial continuity potentially brings a new insight into a range of disorders associated with the pelvic region, particularly, the poorly understood problem of chronic pelvic pain. Considering the complex interaction between fascia and pelvic muscles, often noted for their dysfunctional state in pelvic disorders, the fascia surrounding the muscles is a potential mechanism, due to which, muscle generates tension and fascia mediates force transmission, that leads to pain. This pain is often misconstrued as having visceral origin and is frequently labeled as referred pain. Based on the significant contributions of DeLancey, Stoker and others, the work of Carla Stecco and her team provides a seminal evidence-base for a new perspective on the anatomy, function, and dysfunctional states of the pelvic region. From the perspective of an anatomist, such discoveries are most welcomed, encouraged and recommended.

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Different clinicians have varying views of fascia, for surgeons, it may serve as a boarder for dissection, a stable anchor for sutures or a location of tissue herniation that requires repair. For many, it was that white stuff that needed to be dissected out of the way in cadaver lab, oh-so-many-years-ago, in order to isolate a well delineated structure that would soon have a numbered pin placed in it that required identification for a lab quiz. Like all things in life, fascia and the fascial system holds differing paradigms depending on the viewpoint of the clinician. With the emergence of research we now know that fascia is much more than aponeurotic sheets, ligaments and the ubiquitous packing material occupying space in between anatomic structures. It contains a vast neural network capable of generating signals of proprioception and nociception as well as reacting to and transmitting mechanical loads.

The value of this article lies in the clear stated goal of providing a greater understanding of the continuity of the fascial system between the abdominal wall, pelvic floor and lumbar region which had not previously been established in the literature. The abdominopelvic canister is a functional and anatomical construct based on the continuity of the somatic structures of the abdominal cavity and pelvic basin. The superior boarder of the canister being the respiratory diaphragm and the inferior boarder, the pelvic floor. The canister acts synergistically to support the midline of the body and altered mechanics, be it of a lack of support, altered respiration or excessive motor holding are well established as contributing to the development of pelvic dysfunction.

As medicine has moved away from the Cartesian model – where chronic persistent pain was believed to be a direct result of tissue damage – to a greater understanding that pain is an output from the brain as a result of threat, perceived or real, we must adjust our diagnoses and treatments accordingly. The focus of chronic pelvic pain is also moving away from the paradigm of assumed organ pathology to a greater understanding of the contribution of the musculoskeletal system which includes fascia as a generator of nociception and altered proprioception. Scars of the abdominal wall as well as lumbosacral dysfunction have been reported in the literature as a source of persistent pain. The knowledge of the signaling function of fascia and the new established continuity between the abdomen, pelvic floor and low back provides another area of consideration for potential sources of nociceptive input to the brain.

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It is a pleasure to comment on Dr Stecco's concept of a universal fascial system, in this instance, its relevance to the pelvic floor. The role of connective tissue in pelvic floor function and dysfunction has been a recurent theme in this journal since its inception some 10 years ago. The word 'fascia' is not a well defined concept in pelvic floor anatomy. In a general sense it is a structural component which refers to the connective tissue covering organs, muscles, pelvic side wall. Ligaments have historically been defined as a condensation of this fascia. On dissection 'fascia' appears white and it is often assumed that this is a purely collagenous layer. Nothing could be further from the truth. Biopsies of ligaments, 'fascial' layers of vagina and attachments between organs have all given the same results: collagen, elastin, smooth muscle, blood vessels and nerves, fig1, albeit in different proportions. It follows from figure 1, that all pelvic functions involving the organs muscles and ligaments will involve a cortically co-ordinated contraction or relaxation of the 'fascia' in some way. Fascia is indeed a living contractile tissue.

The Integral Theory intersects with Dr Stecco's holistic concepts. It describes how bladder and bowel are opened and closed by striated pelvic muscles pulling against suspensory ligaments. If the ligaments are loose, organ closure is deficient (incontinence) and also, opening (evacuation problems). The most vulnerable structural components of the ligaments are collagen and elastin, both of which deteriorate with age.

This cortically co-ordinated relationship between striated muscle, smooth muscle and ligaments/fascia explains many so-called mysteries of the pelvic floor. How strips of tape strategically placed on ligaments restore continence (TVT operation): the contractile strength of the urethral closure forces is restored. Pelvic muscles become unbalanced when a forward or backward vector forces is weakened: the opposite vector contracts excessively causing muscle spasm and pain. How inability of loose uterosacral ligaments to be tensioned may cause referred pain along the T11-12 S2-4 nerve plexuses. Clearly the pelvic fascial/ligamentous tissues must be related to the general fascia as described in Dr Stecco's universal theory. This raises two fascinating questions, how and by how much?

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"Fascial continuity of the pelvic floor with the abdominal and lumbar region" in my opinion opens a very interesting addition to the established aspects of the Integral Theory. Due to its extraordinarily detailed review of the recent literature and clinically orientated conclusions it contributes valuably to the understanding of the pelvic floor anatomy and its connection to other regions of the human body in a holistic manner. If anything at all, the critical reader possibly would miss a quick view into Embryology, as one would also find elements of these findings e. g. in some of the publications by H. Fritsch and associates (such as Ann Anat. 1993 Dec;175(6):531-9: "Development and organization of the pelvic connective tissue in the human fetus.", or Surg Radiol Anat. 1994;16(3):259-65: "Topography and subdivision of the pelvic connective tissue in human fetuses and in the adult", or more recently in Adv Anat Embryol Cell Biol. 2004;175:III-IX, 1-64: "Clinical anatomy of the pelvic floor." These papers would as well support the correctness of the conclusions drawn, and I am thoroughly stretched of what influence on clinical practice this will gain in the future.

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