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THE PELVIC FLOOR MUSCLES OF THE RHESUS MACAQUE

Hypothesis / aims of study

We aim to compare the pelvic floor muscles (PFM) of the female rhesus macaque to the PFM in women.

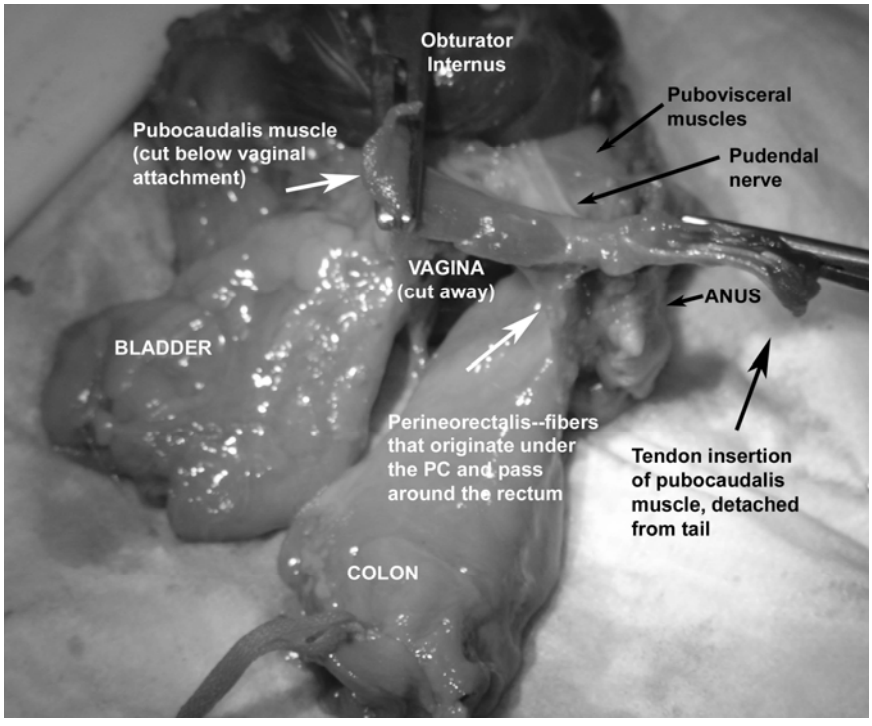
Study design, materials and methods

Anatomic dissection was performed in 120 fresh macaque cadavers to identify the origins and insertions of the PFM, and their attachments to the pelvic organs. Dissection of the muscles around the distal urethra, vagina and rectum was limited by dense connective tissue. This region was studied in serial histologic cross sections cut from paraffin-embedded tissue from 5 animals. Magnetic resonance images (MRI) (T1-weighted and TSE proton-density, 3 Tesla Siemens Trio) were obtained from 3 animals with the pelvis centered in a knee coil. The muscles in this report are named according to their origins and insertions, and compared to human levator anatomy using the same naming system.[1]

Results

The pubocaudalis (PC) has an aponeurotic origin from the superior aspect of the pubic ramus and inner surface of the symphysis and it inserts on the 2nd and 3rd caudal (tail) vertebrae (CV). The PC passes along the medial surface of the obturator internus, but has only filmy attachments. The mid vagina is densely adherent to the PC, with a perpendicular orientation to the muscle fibers. The PC acts to flex the tail, and simultaneously moves the mid vagina toward the symphysis. The iliocaudalis (IC) has a fleshy origin from the inner surface of the ilium and fuses with the PC to insert on the 2nd and 3rd CV. The rectum overlies CV 1-3 and has a small muscular attachment to those vertebrae. The PC and IC act to move the rectum toward the symphysis with flexion of the tail. The musculotendinous coccygeus originates from a rudimentary ischial spine and adjacent ischium and inserts on the lower sacrum and CV 1-3. The pudendal nerve passes under this muscle as it travels to the perineum and is tethered at this location. The rhesus macaque also has pubovisceral muscles that are embedded within dense connective tissue, making it difficult to clearly identify origins and insertions by gross dissection.

Figure 1. Gross dissection of pelvic muscles and organs—lateral view
This gross dissection shows the relationship between the PC, the pubovisceral muscles, and the pelvic organs. The vagina and paravaginal attachment has been removed, showing the PC muscle as it passes to the tail. The pubovisceral muscles have two components—a distal portion densely adherent to the lateral vaginal wall and anus, and a proximal portion that arises under the PC and passes around the rectum.



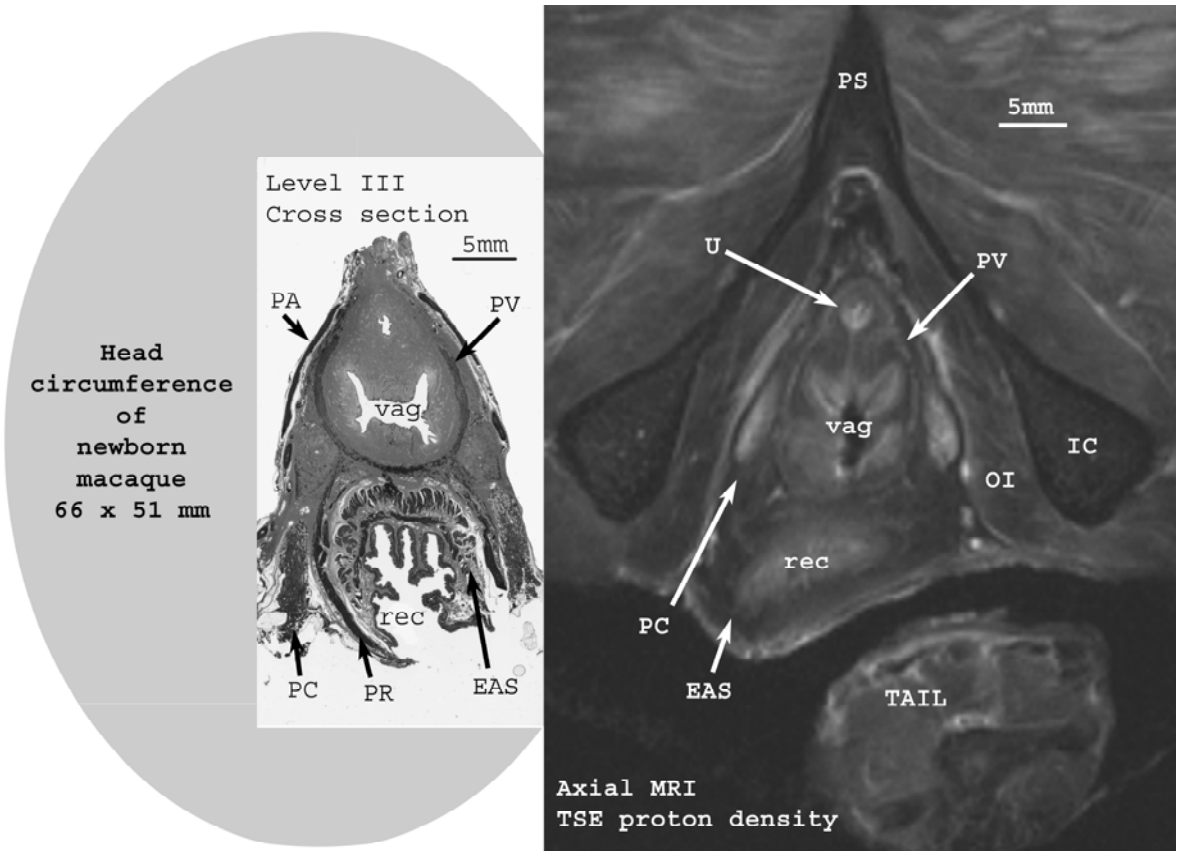


Figure 2. Comparison of histology and MR imaging at similar scale. The left image is a cross-section, stained with Masson's trichrome, taken 7mm proximal to the introital skin (total vaginal length=3.4 cm). The right image is an axial MRI section from the same region. The grey ellipse represents the size of a newborn cranium, drawn to scale with the other images.

The histologic sections show puboanalis (PA) and pubovaginalis (PV) muscles. The PA inserts into the external anal sphincter (EAS) distally. The rhesus has a perineorectalis (PR) which arises from the perineal body underneath the PC and inserts in a midline raphe behind the rectum, above the level of the EAS.

The MRI image shows the relationship to bony structures, the pubic symphysis (PS) and the ischial callosities (IC). The macaque has a narrow ischio-pubic arch and this directs the cranium more posteriorly during vaginal delivery compared to human birth. The obturator internus (OI) muscle can be seen within the pelvis and passing behind the ischial ramus on the way to its femoral insertion. The flexed tail can be seen adjacent to the rectum. Visualization of the pelvic floor muscles is limited in the rhesus compared to human women due the paucity of fatty tissue between muscle layers. The PV muscle is clearly visualized in this image and the PC muscle is visible in most sections. The puboanalis and perineorectalis are more difficult to distinguish by MRI,

Interpretation of results

The PFM of the rhesus macaque have a pubovisceral component that provides support to the pelvic organs and is highly similar to the PFM of women. The muscle and connective tissue surrounding the distal vagina must lengthen 4-6 fold to accommodate vaginal delivery.

Concluding message

Portions of the PFM are likely susceptible to stretch injury during vaginal childbirth, making the rhesus macaque an excellent model for studying childbirth injury.

1. *Levator ani muscle anatomy evaluated by origin-insertion pairs.* Obstet Gynecol, 2004. **104**(1): p. 168-73.

FUNDING: National Institutes of Health HD38673 and RR00163