Randomized trial of cesarean vs vaginal delivery for effects on the pelvic floor in squirrel monkeys

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OBJECTIVE: Vaginal delivery is a risk factor in pelvic floor disorders. We previously described changes in the pelvic floor associated with pregnancy and parturition in the squirrel monkey, a species with a humanlike pattern of spontaneous age- and parity-associated pelvic organ prolapse. The potential to prevent or diminish these changes with scheduled cesarean delivery (CD) has not been evaluated. In a randomized, controlled trial, we compared female squirrel monkeys undergoing spontaneous vaginal delivery with those undergoing scheduled primary CD for pelvic floor muscle volumes, muscle contrast changes, and dynamic effects on bladder neck position.

STUDY DESIGN: Levator ani, obturator internus, and coccygeus (COC) muscle volumes and contrast uptake were assessed by magnetic resonance imaging in 20 nulliparous females examined prior to pregnancy, a few days after delivery, and 3 months postpartum. The position of bladder neck relative to bony reference line also was assessed with abdominal pressure using dynamic magnetic resonance imaging.

RESULTS: Baseline measurements of 10 females randomly assigned to scheduled primary CD were not different from those of 10 females assigned to spontaneous vaginal delivery. Levator ani and obturator internus muscle volumes did not differ between groups, while volumes were reduced ($P < .05$) in the observation immediately after pregnancy. The COC muscles increased ($P < .05$) immediately after delivery for females in the spontaneous vaginal delivery group, but not for females in the scheduled CD group. Position of the bladder neck descended ($P < .05$) by 3 months postpartum in both groups.

CONCLUSION: Scheduled CD diminishes changes in COC muscle volume and contrast reported to be associated with spontaneous vaginal delivery in squirrel monkeys. However, pelvic support of the bladder was not protected by this intervention suggesting that effects of pregnancy and delivery are not uniformly prevented by this procedure.

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Background and Objective

The etiology of pelvic organ prolapse is multifactorial; vaginal delivery has been consistently shown to be a risk factor. It also has been thought to result from direct damage to the muscles or associated connective tissues during parturition. Cesarean delivery (CD) has been proposed as a protective factor.

The squirrel monkey is an excellent animal model developing dystocia during parturition requiring CD and changes in the pelvic support structures resulting in prolapse. The coccygeus (COC) muscle, within the posterior pelvis in squirrel monkeys, is correlated to the pubo-COC, a component of the levator ani (LA) muscle complex, anteriorly located in human beings, as they both undergo significant strain, stretch, and injury during parturition.

To determine whether parturition-related changes in pelvic floor muscle volume and contrast changes could be prevented or diminished by CD, we conducted a randomized controlled trial of scheduled primary CD in nulliparous females.

Materials and Methods

Female squirrel monkeys were evaluated with magnetic resonance imaging (MRI) prior to pregnancy. Once conception was confirmed, pregnancy was dated and monitored with ultrasound. Because spontaneous delivery was estimated to occur after 147 days of gestation, CD was planned for 144-147 days of gestation. Animals were randomized by computer-generated sequence number to assign 10 females to spontaneous vaginal delivery and 10 to scheduled CD.

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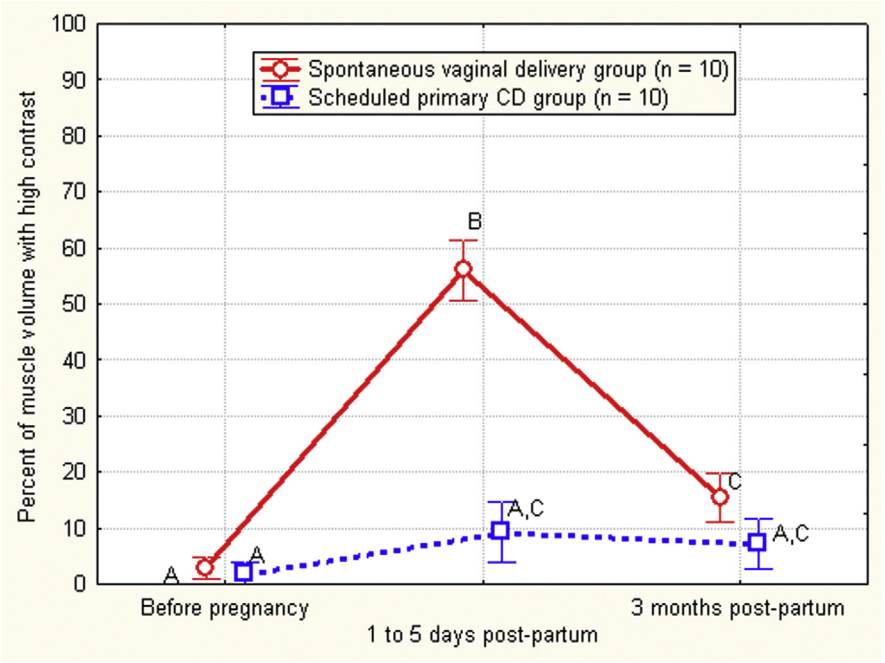
FIGURE
Effect of delivery on COC muscle volume



Comparison of percentage of coccygeus (COC) muscle volume with high contrast within groups using analysis of variance with repeated measures. Groups differ ($P<.0001$), times differ ($P<.0001$) and interactions are significant ($P<.0001$). Means labelled with different letters, differ ($P<.05$) using Duncan's post-hoc test. Contrast levels for animals in scheduled primary cesarean delivery (CD) group remained unchanged throughout the study interval.

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MRI was performed of the pelvic floor from L7-C4. A dynamic series of 20 sagittal images along the midline was obtained to evaluate the position of the bladder neck relative to bony landmarks.

High-resolution gradient echo sagittal views were reformatted as 224 axial views to obtain muscle volume and contrast intensity measurements. Image files were processed for review, manipulation, measurement, and analysis. The left and right sides of the obturator internus (OI), LA, and COC muscles were traced by authors blinded to mode of delivery. We determined the average volume for each paired muscle group. The pelvic outlet diameter (distance between the inferior lateral margins of the obturator foramina at the level of the pubic arch) was measured in an axial MRI.

Results

Baseline evaluations of both groups were similar for age, body size, and pelvic floor measurements, including muscle volume, bladder neck position with abdominal pressure, and width of the bony pelvic outlet.

Changes were associated with parturition in all 3 pairs of pelvic floor muscles. For LA and OI muscles, these changes were represented by a reduction in volume immediately after delivery that returns to prepregnancy values by 3 months postpartum. In contrast, the COC muscles increased in volume following spontaneous vaginal delivery, but not CD. This results in a significant difference between delivery modes ($P < .0001$) (Figure). The outlet diameter was increased after completion of pregnancy regardless of mode of delivery. All animals were noted to have descent of the bladder neck, regardless of delivery mode, with no prolapse visualized on exam.

Comment

Prospective randomized trials to attribute specific causes of pelvic floor injury have remained difficult to conduct in human beings. Female squirrel monkeys have been found to develop defects in the pelvic floor as a result of risk factors of increased parity and age. Like human beings, they deliver large babies through small pelvises. This similarity makes them an excellent species for human comparison of normal progression of pelvic floor changes after pregnancy and parturition.

We anticipated that scheduled CD without labor would prevent COC injury and the subsequent effects on bladder descent. Although COC muscle was preserved in those undergoing CD, effects on bladder descent were not prevented. We do not yet know the relationship of COC muscle changes to pelvic organ prolapse; however, repeated injury due to additional pregnancies might cause irreversible damage over time. This theory will be further examined as we follow up our cohort through additional pregnancies. This prospective trial shows that avoiding engagement into the pelvis and vaginal delivery prevents this muscle injury.

It is interesting to note that the other muscles in the squirrel monkey pelvic floor, LA and OI, were similarly affected in both the vaginal delivery and CD groups by decreasing in volume. We are unsure whether this was due to stretch or atrophy. The COC muscle is the area where effects of stretch induce edematous change. The LA and OI muscles may be protected by the fixed symphysis so that stretch is not sufficient to produce trauma. Regardless of mode of delivery, outlet diameter measurements increased after pregnancy.

Strengths of this study include the ability to compare muscles at several time intervals within each subject and to randomize animals to either treatment group, which decreased selection bias and eliminated various confounders. We have established a reliable evaluation of female squirrel monkeys as an appropriate comparison for the human female pelvis. Similarities in the development of pelvic floor dysfunction allow us to observe the progression of pelvic floor disorders and document changes over time.

Our study identifies significant changes to the pelvic floor muscles as a

result of vaginal delivery that can be prevented by elective primary CD in this animal model. However, loss of support associated with pregnancy and vaginal delivery was not prevented.

CLINICAL IMPLICATIONS

- Similarities in the development of pelvic floor dysfunction in human vs squirrel monkey pelvic floor anatomy permit the observation of the progression of pelvic floor disorders and documentation of changes over a shorter time in the animal model.
- The anterior pelvis of the monkey, where the levator ani and obturator internus muscles are located, may be protected by the fixed pubis symphysis, whereas the coccygeus is more vulnerable to injury due to the widening of the posterior pelvis to accommodate the fetus.
- Regardless of delivery mode, outlet diameter was found to increase after pregnancy and parturition.
- Elective cesarean delivery prevented damage to pelvic floor muscles but not loss of pelvic organ support. ■