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SCHISTOSOMUS REFLEXUS–LIKE MALFORMATION IN A SOUTHERN WHITE RHINOCEROS (*CERATOTHERIUM SIMUM SIMUM*)

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Abstract: A 7.5-yr-old female southern white rhinoceros (*Ceratotherium simum simum*) aborted spontaneously at approximately 13 mo gestation. The fetus exhibited malformations consistent with schistosomus reflexus syndrome, including spinal inversion and ventral midline abdominal defect with externalization of abdominal viscera. A computed tomography was performed and revealed severe scoliosis, a spiral rotation of the spine, multiple vertebral anomalies, hypoplasia of multiple bones of the skull, and mild prognathism. This is the first report of schistosomus reflexus–like syndrome in a nondomestic species, and the first report to characterize these skeletal changes by three-dimensional computed tomography.

Key words: Abortion, *Ceratotherium simum*, computed tomography, congenital, schistosomus reflexus, white rhinoceros.

BRIEF COMMUNICATION

Schistosomus reflexus (SR) is a rare syndrome involving a constellation of congenital defects typically including spinal inversion, ventral abdominal defect with eventration of abdominal viscera, limb ankylosis, and lung and diaphragm hypoplasia.[7] Other congenital abnormalities reported in conjunction with these features have included thoracoschisis with thoracic eventration, segmental intestinal atresia, abnormal orientation of viscera, urogenital anomalies, nonunion of the pelvic symphysis, and other skeletal anomalies such as prognathia, scoliosis, and reduced number or fusion of vertebrae and ribs.[7]

Schistosomus reflexus is most commonly reported in cattle.[7] Other species reported to be affected by a SR-like syndrome include small ruminants, the cat, dog, horse, donkey, and camel.[1,3,4,8,10,11]

The southern white rhinoceros (*Ceratotherium simum simum*) is native to eastern and southern Africa and is the most abundant rhinoceros species in the wild.[5,9] Nevertheless, for reasons incompletely understood, the reproductive success of captive-born white rhinoceros is low, such that captive populations are not self-sustaining.[5] Although early embryonic loss and stillbirth have been reported, reports of congenital abnormalities in rhinoceros are limited to isolated cases of cranioschisis with cerebral aplasia, cyclopia, and ocular dermoid in the Indian rhinoceros (*Rhinoceros unicornis*).[5,12] In this report, we present findings consistent with a SR-like syndrome in an aborted late-term southern white rhinoceros fetus.

The dam was a 7.5 year old female born at Disney's Animal Kingdom (Orlando, Florida, USA) in 2005. The sire was an approximately 18-yr-old male originating from a reserve in Africa. The dam of this report was pregnant once 2 yr prior in 2010 by the same bull; this calf was aborted at an estimated 70–80 days gestation per fecal hormone profile. The body of the fetus was not found and the cause of the abortion was not determined. The bull had a history of one other abortion with the mother of the dam of this report in 2010, and had previously successfully sired two calves with that female.

In November 2012, at an estimated 13 mo out of the approximately 16-mo gestation period, the animal began exhibiting contractions at 8-min intervals and fetal membranes were noted to be protruding from the vulva. A nonviable fetus was passed without assistance and was submitted for necropsy. The dam remained in good health throughout the episode.

The fetus was male, weighed 25 kg (normal weight of white rhinoceros at birth: 40–65 kg), and was in moderately autolyzed condition, suggesting recent in utero death.[9] The carcass was

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covered by the placenta, which exhibited no gross abnormalities. There was an approximately 10 × 5–cm smooth-edged ventral midline defect in the abdominal wall extending from the xyphoid process to the pubis with eventration of abdominal viscera, including the liver, stomach, small and large intestine, spleen, kidneys, and adrenal glands. The abdominal walls were markedly shortened, with significant reduction in volume of the abdominal cavity. There was greater than 90-degree scoliosis of the lumbar spine with abrupt displacement of the pelvis cranially and to the left (Fig. 1). The thoracic and pelvic limbs exhibited normal orientation and ankylosis was not present. The intestinal tract was patent and the colon contained meconium.

The carcass was frozen and computed tomography (CT; Toshiba Aquilion 8, Tustin, California 92780, USA) was performed; CT documented multiple skeletal deformities. The most notable deformity was severe scoliosis of the lumbar, sacral, and coccygeal spine that included an acute, 120-degree leftward angulation centered at the thoracolumbar junction. Associated with this angulation, there were multiple compressed and partially fused cranial lumbar vertebral segments as well as partial fusion of multiple left-side ribs. There was also a progressive rotational deformity of the thoracic and lumbar spine, ultimately resulting in a 45-degree clockwise rotation of the pelvis relative to the shoulders when from the cranial-to–caudal view. These spinal anomalies resulted in dorsal displacement of the pelvis relative to the lumbar spine. In addition to the spinal anomalies, there were multiple craniofacial deformities, including a large, 3.5 × 5.5–cm oval defect in the right aspect of the cranium caused by hypoplasia of portions of the right frontal, temporal, and parietal bones. There was also hypoplasia of the dorsal aspect of the left frontal bone, which resulted in an eccentric bregmatic fontanelle. Mild prognathism was also noted (Fig. 2).

Schistosomus reflexus, literally "inside out and bent backwards," is a rare cause of late-term abortion, and is seen primarily in cattle, with reports of SR in up to 1.3% of bovine dystocias.[6] In cattle, an autosomal recessive mode of inheritance is suspected because of case clusters noted in offspring of individual bulls.[2,7] In mice, genes implicated in body-wall closure defects include TGF-β, a family of signaling molecules, and AP-2, a family of transcription factors.[8] Targeted mutagenesis of the genes TGF-β2, TGF-β3, and AP-2 results in a spectrum of congenital defects reminiscent of SR, including thoracoabdomino-

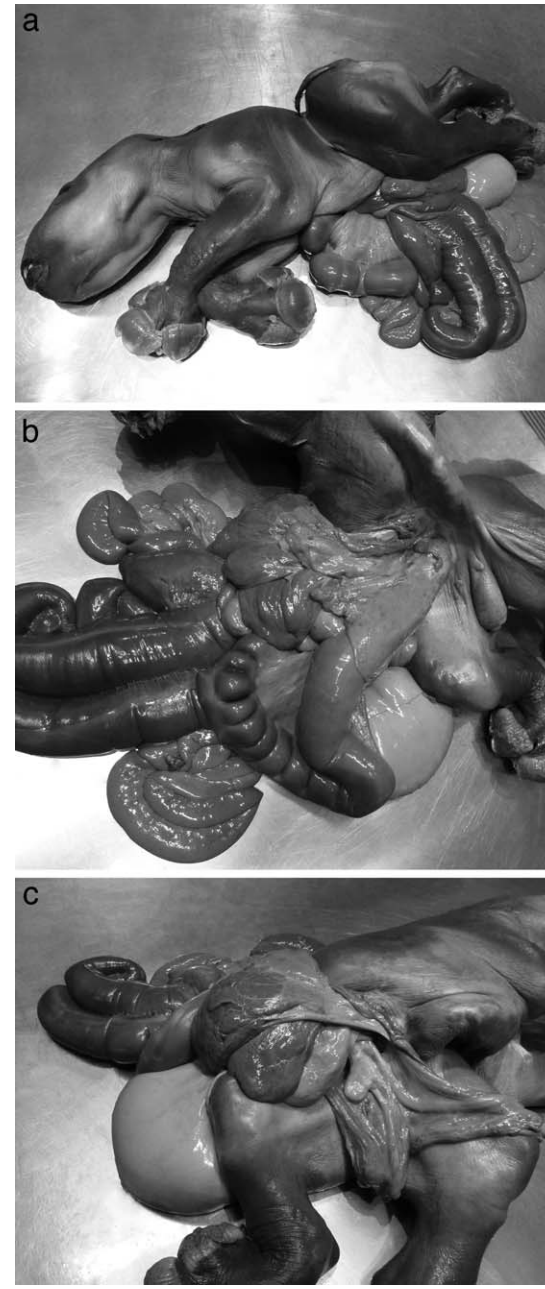

Figure 1. **a.** Southern white rhinoceros fetus exhibiting features of schistosomus reflexus including abdominoschisis with eventration, lumbar scoliosis, and dorsolateral displacement of the pelvis. **b.** Abdominoschisis with marked reduction of abdominal cavity volume and eventration of abdominal viscera. **c.** Abdominal defect with exposure of the liver, urinary bladder, and umbilical arteries.

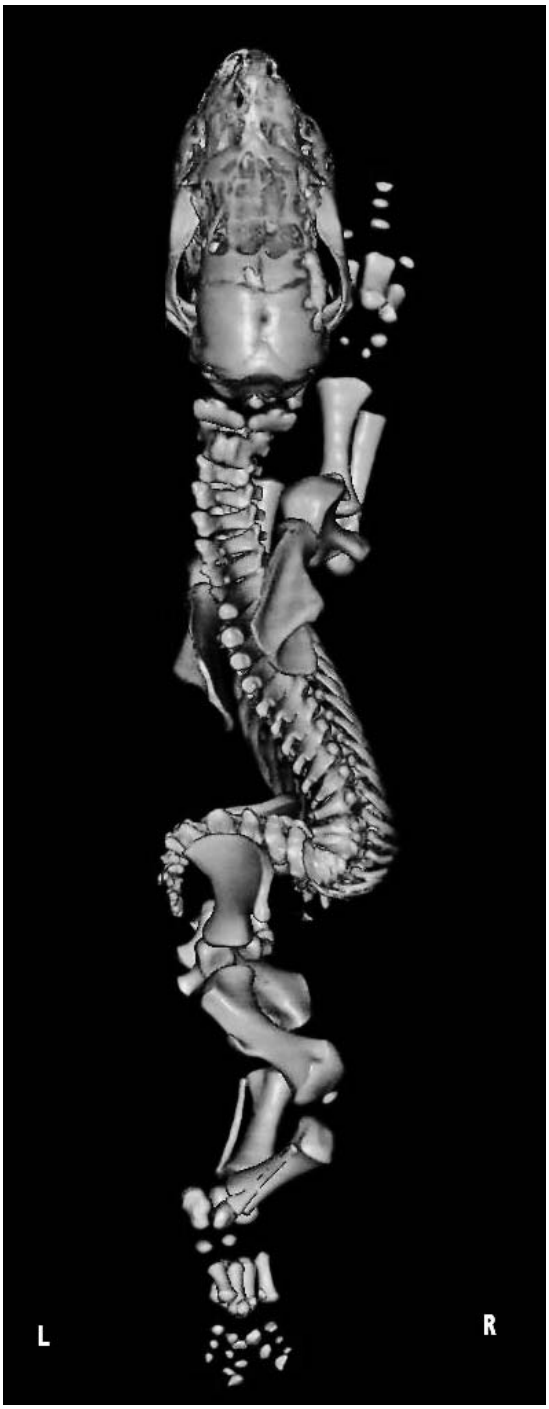

Figure 2. Computed tomography with three-dimensional reconstruction, dorsoventral view. There is rotation of the thoracic and lumbar spine; scoliosis of the lumbar, sacral, and coccygeal spine; compression and fusion of lumbar vertebrae; dorsal displacement of the pelvis; and hypoplasia and asymmetry of cranial bones.

schisis with eventration, cardiac, pulmonary, cranial and limb anomalies, and urogenital defects.[8] In the case of this report, the sire of the SR calf has been associated with at least three episodes of abortion, as well as at least two successful births. It is difficult to speculate on potential implications of this history given the low success rate of captive rhinoceros reproduction, but a genetic component cannot be ruled out in this case.

Features of the present case consistent with true SR include spinal inversion, abdominoschisis, and eventration of abdominal viscera. Limb ankylosis, another reportedly defining feature of SR, was not present. Other features present in this case include scoliosis and rotation of the spine, rib fusion, hypoplasia of the bones of the calvarium, and mandibular prognathism. To the authors' knowledge, calvarial hypoplasia with incomplete fusion of the frontal, temporal and parietal bones has not been reported previously in association with SR, although these features bear some resemblance to anomalies recently described in an Indian rhinoceros. In this report, fetal abnormalities were limited to the skull and brain and included cranioschisis with hypoplasia of the parietal and frontal bones.[12]

This is the first report of a SR-like congenital abnormality in a rhinoceros and in a nondomestic species. Computed tomography is a useful modality to characterize skeletal malformations that may not be apparent on gross examination.

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