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Short Communication

Tail trifurcation in the lizard *Salvator merianae* (Squamata: Teiidae) investigated by computer tomography

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A lizard uses its tail for a great variety of functions aside from its most renowned use as an antipredator device by tail autotomy (Arnold 1984). For example, tails provide balance during locomotion (Ballinger 1973), are used for fat storage (Daniels 1984), and may signify social status of the lizard (Fox *et al.* 1990). Therefore, tail regeneration is essential to ensure the survivorship and reproduction of lizards (Bateman and Fleming 2009).

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Lizards can repair many kinds of tissues (e.g., muscular, osteological and neuronal) that are essential to tail regeneration (Alibardi 2010). However, the regeneration is not always perfect, and there are many records of tail abnormalities, such as warped and curly tails, but mainly possession of multiple tails. These morphological anomalies are usually attributed to failures in tail regeneration process (Bellairs and Bryant 1985), which may generate two or, less frequently, three or more tips.

Tail bifurcation (or possession of a "forked" tail) is widely recorded in the following families: Agamidae (Ananjeva and Danov 1991), Anguidae (Banta 1963), Gekkonidae

(Kumbar *et al.* 2011), Gymnophtalmidae (Pheasey *et al.* 2014), Iguanidae (Hayes *et al.* 2012), Lacertidae (Dudek and Ekner-Grzyb 2013), Polychrotidae (Goin and Goin 1971), Phrynosomatidae (Mata-Silva *et al.* 2013), Scincidae (Vrcibradic and Niemeyer 2013), Teiidae (Bateman and Chung-MacCoubrey 2013), and Tropiduridae (Martins *et al.* 2013, Martinelli and Bogan 2013, Passos *et al.* 2014). However, tail trifurcation (also cited as "trifurcated" tail) and other supernumerary caudal anomalies seem to be uncommon, having been reported only in Gymnophtalmidae (Pheasey *et al.* 2014), Iguanidae (Hayes *et al.* 2012), Lacertidae (Koleska and Jablonski 2015), Phrynosomatidae (Mata-Silva *et al.* 2010), Gekkonidae (Crouch 1969), and Teiidae (Trauth *et al.* 2014). Herein we increase the knowledge on multiple tails in lizards assessing an anomalous trifurcated tail of *Salvator merianae* using a high definition imaging technology.

In August 2013, an apparently sick lizard was found by employees of the Centro Operacional de Desenvolvimento e Saneamento de Uberaba (CODAU) in an anthropic area from Uberaba Municipality in the state of Minas Gerais in southeastern Brazil—19º45'13" S, 47º55'48" W. The lizard was taken to the Veterinary Hospital from the Universidade de Uberaba (UNIUBE). The individual was notably unhealthy. It had limited mobility, body injuries, morphological abnormalities in the tail, and despite veterinary care, it died within a few days. The lizard was scanned by computer tomography (CT) at the Centro de Diagnóstico por Imagem from the Universidade Federal do Triângulo Mineiro (UFTM), fixed in 10% formalin, preserved in 70% ethanol solution, and housed in Zoological Collection of Complexo Cultural e Científico de Peirópolis (CCCP) from UFTM, Uberaba, under the voucher number CCCP-Zo 110. The X-ray computer tomography examination was conducted in a Toshiba Aquilion®64 CT scanner with images of 0.5 mm thickness and 0.25 mm between them, and a 3D model was built by interpolation of 881 CT images in the software InVesalius 3.0 beta 4.

The specimen described here was an adult female of *Salvator merianae* (Duméril and Bibron, 1839) with a snout–vent length of 36 cm. It had two deep dorsolateral injuries on each side of the base of the tail and its tail was trifurcate (Figure 1). The main axis of the tail (36.2 cm) had typical scutellation and no evidence of regeneration (Figure 2). The other two branches emerged at about 26 cm on the right side of main tail axis, and the distinctive color and shapes of the re-grown scales (Figure 2) clearly indicated that these tails were regenerated. The larger secondary branch was 6.4 cm forming an angle of 48º with the main tail axis, and the smaller one was 1.5 cm with an angle of 35º.

The CT revealed a fractured vertebra close to the pelvic girdle and some fractured ribs, which likely caused the lizard's impaired locomotion. In spite of severe injuries in tail base, there was no evidence of bone lesions in that region (Figure 1). The secondary tails originated at two distinct points from the main tail and their origins were separated by at least one caudal vertebra (Figure 2). At the proximal point of branching, the about four vertebrae of the main tail curved to the left and the two additional tail branches emerged from the opposite side (Figure 2). The CT scan and necropsy showed that both of the secondary tails were constituted mainly by a hollow cartilaginous rod.

Salvator merianae recently was resurrected from synonymy with *Tupinambis* (Harvey *et al.* 2012), and is one of the largest species of lizard from the New World, reaching more than 40 cm snout–vent length (Péres-Junior 2003). The species is widely distributed through South America in seasonally dry environments, such as Caatinga, Cerrado, and Chaco, as well as open areas in Amazon and Atlantic Rainforests (Ávila-Pires 1995). Because of its broad distribution and abundance, *S. merianae* has been target of some osteological (Arias and Lobo 2006, Brizuela and Albino 2010) and myological studies (Rieppel 1980, Casals *et al.* 2012). On the other hand, published information on

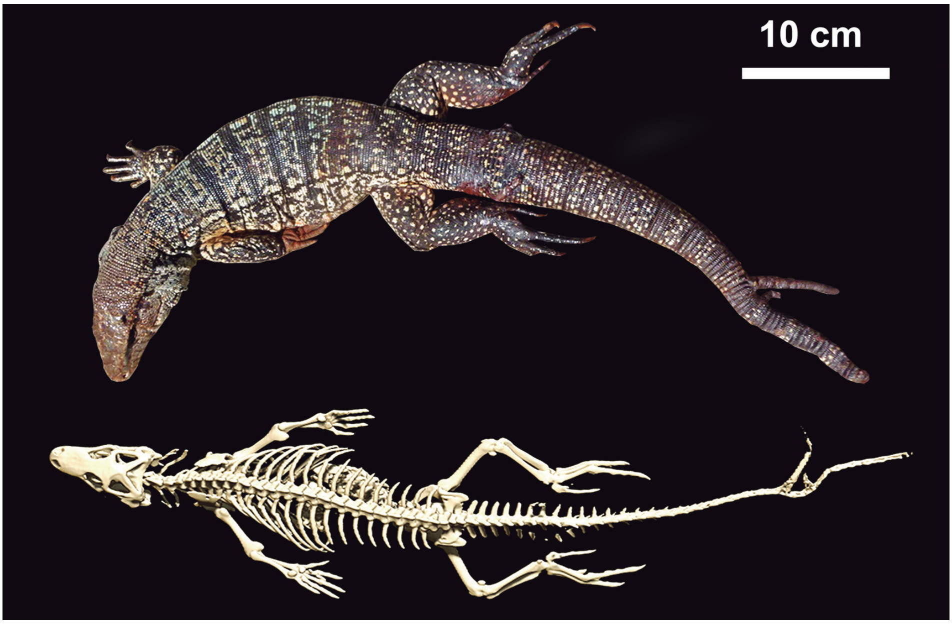

Figure 1. Adult female of *Salvator merianae* (CCCP-Zo 110) with an anomalous trifurcated tail from Uberaba Municipality in the state of Minas Gerais in southeastern Brazil. Note the unhealed injuries in tail base (above), and the skeletal morphology (below).

Figure 2. Details of tail trifurcation in *Salvator merianae* (CCCP-Zo 110). Note the distinct color and shape of regenerated scales in the secondary tails (left), and the two independent origin points of them (right).

morphological abnormalities in this species is still missing (Pelegrin and Leão 2016). Our findings demonstrate that in *S. merianae*, anomalous tails may develop from the original tail, and lend support to the thinking that tail furcations in lizards arise as a result of incomplete tail breaks (Bellairs and Bryant 1985). The last compilation of histological information on tail regeneration in lizards brings some specific insights on supernumerary tails (Alibardi 2010). Laboratory experiments to induce tail regeneration showed that spinal cord implantation stimulates formation of additional tails, demonstrating the role of spinal cord as promoter of tail furcations (Alibardi 2010). However, in view of the wide dissimilarities in the caudal regeneration process among different lizard lineages, the current knowledge still hamper us to infer general conclusions about natural tail furcations.

In fact, there are growing numbers of records on tail abnormalities in lizards, but the majority of them simply report the occurrence of the phenomenon in a given species. With the exception of a few contributions (e.g., Hayes *et al*. 2012, Martins *et al*. 2013), there are no deeper morphological or ecological investigations on tail furcation in lizards. In other words, the causes and consequences of multiple tails in lizards still remain to be understood. Our findings revealed anatomical details hitherto unknown about the process of tail furcation, documenting and highlighting the need to examine these morphological abnormalities in the kind of detail possible with high-definition imaging technologies.

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