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# Evaluation of maxillary arterial blood flow in anesthetized cats with the mouth closed and open

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ABSTRACT

The mouth-gag is a common tool used in veterinary medicine during oral and transoral procedures in cats but its use has recently been associated with the development of blindness. The goal of this study was to investigate whether maximal opening of the mouth affects maxillary artery blood flow in six anesthetized cats. To assess blood flow, the electroretinogram (ERG), brainstem auditory evoked response (BAER) and magnetic resonance angiography (MRA) were evaluated qualitatively with the mouth closed and open. During dynamic computer tomography (CT) examinations, detection of contrast medium in the maxillary artery was quantified by measuring the Hounsfield units (HUs). The peak HU, time to peak and mean HU were determined. Changes ⩾10% of these parameters were considered indicative of altered blood flow.

ERG and BAER were normal with the mouth closed in all cats, but was abnormal with the mouth opened maximally in two cats and one cat, respectively. During MRA, blood flow was undetected in either maxillary artery in one cat and reduced in the right maxillary artery in two cats, when the mouth was open. During CT, the peak HU decreased ⩾10% in three cats, the time to peak was ⩾10% longer in two cats, and the mean HU was ⩾10% lower in one cat when the mouth was open. No cat developed apparent blindness or deafness. Maximal opening of the mouth caused alterations in several indicators of blood flow in some individual cats.



## Introduction

Temporary and permanent blindness or deafness has been reported in cats following general anesthesia (Jurk et al., 2001; Stiles et al., 2012; Falzone and Lowrie, 2011; Son et al., 2009; Stevens-Sparks and Strain, 2010). Although infrequent, these complications can be devastating to feline patients and to cat owners and have resulted in the euthanasia of some cats. The pathogenesis of these complications is essentially unknown, but the conventionally proposed mechanism is anesthesia-related decreased oxygen supply to the brain through cardiovascular depression, hypotension or hypoxemia.

Reports documenting blindness or deafness in cats after anesthesia often share a common characteristic and the complications frequently occur after oral or transoral procedures when the mouth is held open by a gag (Stiles et al., 2012). In that investigation, an association between the use of a spring-loaded mouth gag and the development of blindness and central neurological deficits was suggested. Such association is attributed to the feline anatomy in that the internal carotid artery is functionally nonexistent and the maxillary artery, which is the continuation of the external carotid artery, is a major supplier of oxygenated blood to the brain, retina, and inner ear (Davies and Story, 1943; Kumar et al., 1976; Gillilan, 1976). Because the maxillary artery courses around the caudal aspect of the mandible, it might be partially or completely occluded when the mouth is opened maximally. Occlusion might be due to bulging of the pterygoid muscles or to compression by the angular process of the mandible (Fig. 1). During normal activity, this anatomical arrangement is unlikely to cause blindness or deafness because the mouth is rarely opened to the maximum extent for a prolonged period of time. However, the application of a spring-loaded gag in anesthetized cats can result in the mouth being opened beyond the typical range of motion and for a prolonged period of time. It is therefore possible that maximal opening of the mouth is a contributing factor for altering maxillary artery blood flow.

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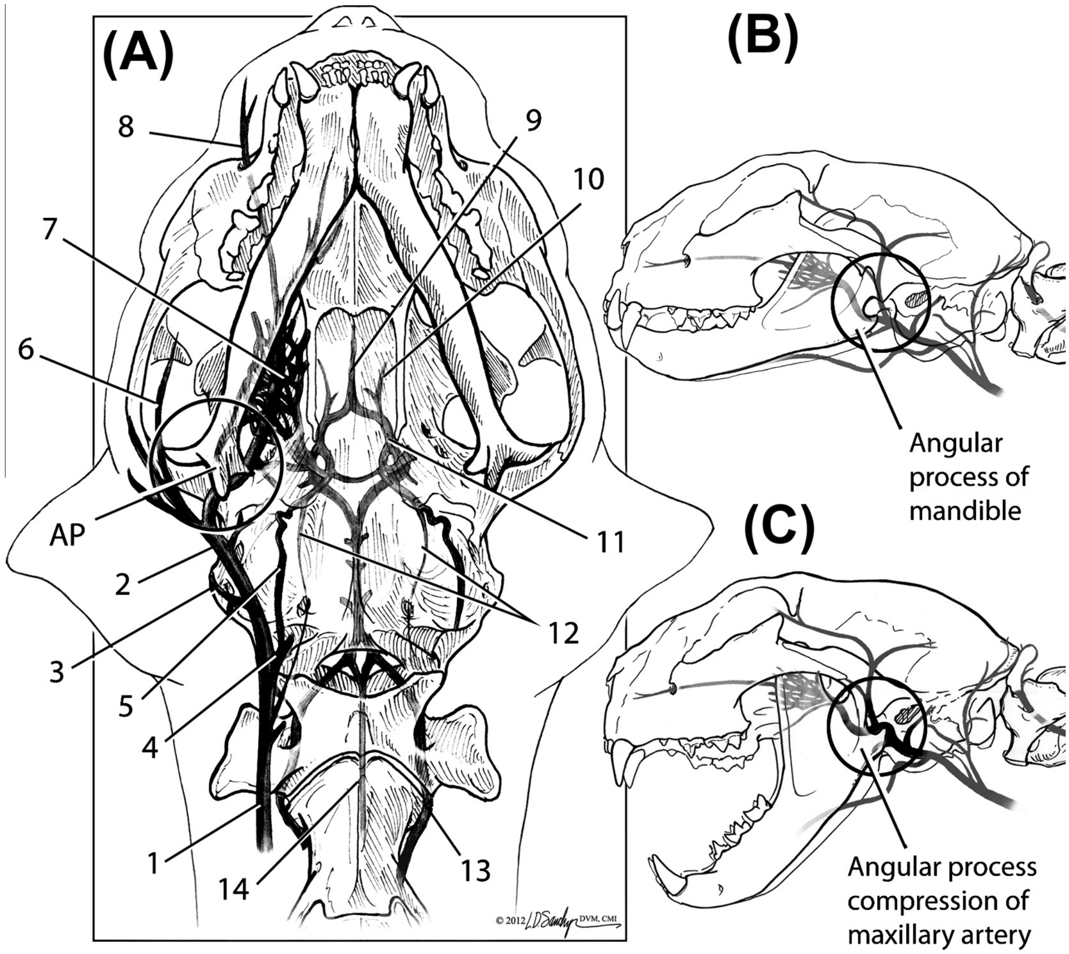


**Fig. 1.** Illustrations showing the primary arterial blood supply to the brain, ears, and eyes via the rete branches of the maxillary arteries. (A) Ventral view of the head and cranial neck. (B) Left-lateral view of the head with the mouth closed. (C) Left-lateral view of the head with the mouth open. Compare (B and C). Note the proximity of the angular process of the mandible and the maxillary artery, and how the relationship varies with mouth positioning. 1 – Common carotid artery, maxillary artery (unlabeled) is included in circle as an extension of (2); 2 – external carotid artery; 3 – occipital artery; 4 – ascending pharyngeal artery; 5 – anastomotic branch of the ascending pharyngeal artery with the internal carotid artery; 6 – superficial temporal artery; 7 – rete mirabile arteria maxillaris; 8 – infraorbital artery; 9 – rostral meningeal artery; 10 – rostral cerebral artery; 11 – cerebral vascular circle (circle of Willis); 12 – internal carotid artery; 13 – vertebral artery; 14 – ventral spinal artery.

The primary objective of this study was to investigate whether opening the mouth alters blood flow in the maxillary artery in anesthetized cats. We hypothesized that maximal opening of the mouth would result in changes indicative of altered blood flow through the maxillary arteries.

## Materials and methods

### *Experimental design*

Cats were evaluated with and without the use of a mouth gag. The dependent variables were electroretinography (ERG), brain auditory evoked response (BAER), quantitative computed tomography (CT) scores, and qualitative three-dimensional, time-of-flight, magnetic resonance angiography (3D-TOF MRA) scores; the independent variable was the presence or absence of the mouth gag. This protocol was approved by the Institutional Animal Care and Use Committee at Cornell University.

### *Animals*

Six healthy adult domestic shorthair cats, with a median age of 1.9 years (1.7–2.7 years) and a median bodyweight of 4.9 kg (4.2–5.4 kg), underwent ERG, BAER, CT, and 3D-TOF MRA examinations twice (with and without the gag in place) during the same anesthetic event; the order of the imaging examinations was randomized by restricted coin toss so that each procedure was done first for three cats.

The animals were sedated with buprenorphine (Buprenex, Reckitt Benckiser Pharmaceuticals; 0.02 mg/kg), acepromazine (Aceproject, Butler Animal Health; 0.02 mg/kg) and ketamine (Ketaset, Fort Dodge Animal Health; 5 mg/kg) IM. An IV catheter was inserted into a cephalic vein and after 5 min of preoxygenation via face mask, general anesthesia was induced with IV propofol (PropoFlo, Abbott Animal Health) given to effect. Cats were intubated and anesthesia was maintained with sevoflurane (SevoFlo, Abbott Laboratories) in oxygen. Spontaneous ventilation was allowed for the duration of the experiment. Lactated Ringer's solution was infused IV at a rate of 5 mL/kg/h. Monitoring included electrocardiogram, pulse oximeter, capnography, non-invasive arterial blood pressure (oscillometric, every 2 min) and rectal temperature. Dopamine (DOPamine, Hospira; 5–10 mcg/kg/min constant rate infusion) or atropine (Atropine, Med-Pharmex; 0.02 mg/kg), was administered IV if hypotension (mean arterial pressure <70 mmHg) or bradycardia (<120 beats/min) occurred. Body temperature was maintained $\geqslant$37.5 °C.

### *Electrodiagnostics*

The effects of mouth opening on the ERG and BAER were evaluated. Anesthetized cats were placed in right lateral recumbency, and ERG and BAER were performed on the left eye and ear by the same investigator. Both examinations were performed twice, prior to imaging. First, the mouth was allowed to close naturally (except for the endotracheal tube), and then it was held open using a spring-loaded mouth gag placed between the right maxillary and mandibular canine teeth. Qualitative ERG and BAER examinations were based on visual interpretation of the waveforms with comparisons before and after mouth opening. The responses were considered abnormal if there was a loss of observable response during low intensity stimulation, or decreases in waveform amplitudes during high intensity stimulation, as well as increases in the time to peak following stimuli (implicit time). Details of the electrodiagnostics techniques are described in Appendix A.