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# Effects of aging on evoked retrusive tongue actions

*Benjamin J. Becker* [a], *John A. Russell* [a], *Nadine P. Connor* [a,b,*]

[a] *Department of Surgery, Division of Otolaryngology—Head and Neck Surgery, University of Wisconsin, Madison, WI, United States*

[b] *Department of Communication Sciences and Disorders, University of Wisconsin, Madison, WI, United States*

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ABSTRACT

*Objective:* Tongue strength, timing, and coordination deficits may underlie age-related swallowing function. Retrusive tongue actions are likely important in retrograde bolus transport. However, age-related changes in retrusive tongue muscle contractile properties have not been identified in animal studies. Because previous studies employed whole hypoglossal nerve stimulation that activated both protrusive and retrusive tongue muscles, co-contraction may have masked retrusive muscle force decrements. The hypotheses of this study were: (1) retrusive tongue muscle contraction forces would be diminished and temporal characteristics prolonged in old rats when lateral nerves were selectively activated, and (2) greater muscle contractile forces with selective lateral branch stimulation would be found relative to whole hypoglossal nerve stimulation.

*Design:* Nineteen Fischer 344/Brown Norway rats (9 old, 10 young adult) underwent tongue muscle contractile property recording elicited by: (1) bilateral whole hypoglossal nerve stimulation, and (2) selective lateral branch stimulation. Twitch contraction time (CT), half-decay time, maximal twitch and tetanic forces, and a fatigue index were measured.

*Results:* For whole nerve stimulation, CT was significantly longer in the old group. No significant age group differences were found with selective lateral nerve stimulation. Significantly reduced twitch forces (old group only), increased tetanic forces and significantly less fatigue were found with selective lateral nerve stimulation than with whole hypoglossal stimulation.

*Conclusions:* Retrusive tongue forces are not impaired in old rats. Deficits observed in swallowing with aging may be due to other factors such as inadequate bolus propulsive forces, mediated by protrusive tongue muscles, or timing/coordination of muscle actions.



## 1. Introduction

Timing and coordination of swallowing behaviours changes with aging such that oral transit times may be increased, multiple swallows per intake may be observed, wet voice may be evidenced, time to relaxation of the upper oesophageal segment may increase, and throat-clearing and coughing may be associated with the swallow, even in people not symptomatic of dysphagia.[1–6] Combinations of subtle strength, timing, and coordination deficits may result in longer-duration swallows that expose the airway to the bolus for a greater

* Corresponding author at: University of Wisconsin, Surgery, Communication Sciences & Disorders, Clinical Science Center, Room K4/711, 600 Highland Avenue, Madison, WI 53792-7375, United States. Tel.: +1 608 265 8711; fax: +1 608 252 0925.
E-mail address: connor@surgery.wisc.edu (N.P. Connor).
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time, potentially increasing the probability of aspiration. The underlying causes of presbyphagia are not known, but have been linked with changes in cranial muscle structure and function. In particular, evidence supports a reduced maximum tongue isometric pressures in older adults.[7–10] While reduced tongue forces during the swallow have not been reported in prior studies of healthy elders, the amount of tongue force used represented a greater proportion of maximal isometric pressure than in younger adults.[7–9] However, reductions in tongue strength have been associated with swallowing deficits[11–13] and tongue exercise-based treatments appear to improve tongue strength[14] and swallowing.[15,16] Accordingly, age-related changes in swallowing may be characterized by both temporal and strength changes, perhaps due to structural and functional decline within the muscles of the tongue.

The extrinsic muscles of the tongue are active during oral preparation of the bolus prior to transport into the pharynx,[17] bolus propulsion,[17] and throughout the entire oropharyngeal swallow.[18] Of the extrinsic muscles, the genioglossus acts to elevate the tongue tip and protrude the tongue, with a primary role in generating tongue-to-palate pressure during the swallow.[19] Motor innervation of the protrusive and retrusive muscles of the tongue is provided by the hypoglossal nerve. Stimulation of the medial branch of the hypoglossal nerve will elicit a tongue protrusion,[20,21] while stimulation of the lateral branch elicits tongue retrusion, via the hyoglossus and styloglossus muscles.[21] The hyoglossus, styloglossus, and the genioglossus are active during oral preparation and retrograde movement of the bolus to the hypopharynx.[18,22,23] Thus, both protrusive and retrusive tongue muscle actions are relevant to the swallow.

Because the hypoglossal nerve provides motor innervation to both retrusive and protrusive muscles of the tongue, stimulation of the whole hypoglossal nerve (proximal to its bifurcation into the medial and lateral branches) will produce a co-contraction of retrusive and protrusive muscles and a net retrusive tongue action.[20,21] Stimulation of the lateral branch of the hypoglossal alone results in tongue retrusion of greater force than that reported whole nerve stimulation.[20,21] Accordingly, co-contraction of protrusive and retrusive tongue muscles serves to reduce force output for evoked retrusive actions. With regard to temporal parameters, contraction times following isolated medial nerve stimulation are faster than both isolated lateral nerve stimulation and whole nerve stimulation.[20] How aging may affect tongue muscle responses to whole nerve stimulation versus isolated lateral nerve stimulation has not been examined.

Decreased swallow function may occur due to a decline in both retrusive and protrusive tongue functions. However, in rats, age-related changes in tongue muscle contractile properties have been found for evoked protrusive[24,25] and not retrusive actions elicited with whole nerve stimulation.[26,27] This is surprising given the retrusive nature of bolus transport during the swallow and previous findings of slower bolus transport speeds during videofluorography in old rats.[28] However, prior data examining retrusive tongue actions were derived by stimulating the whole hypoglossal nerve, and may have been confounded by antagonistic protrusive muscle activity. To examine this possibility, it is necessary to examine retrusive tongue actions following section of the medial branch of the hypoglossal nerve to remove the effects of the genioglossus and to allow precise targeting of the lateral branch and associated retrusive muscles.

The purpose of this study was to determine if age-related changes are manifested in muscle contractile properties of elicited tongue retrusion by whole hypoglossal nerve stimulation and lateral branch hypoglossal stimulation in a rat model. Our hypotheses were that: (1) retrusive tongue muscle contraction forces would be diminished and temporal characteristics prolonged in old rats relative to young adults when the lateral nerve branches are selectively activated, and (2) greater muscle contractile forces with selective lateral branch stimulation would be found relative to whole hypoglossal nerve stimulation in both young adult and old rats. That is, we hypothesized senescence would not alter the previously reported observation of greater tetanic forces with selective lateral nerve stimulation versus whole hypoglossal nerve stimulation.[20,21]

## 2. Materials and methods

This research project was performed according to principles put forth in the NIH Guide for the Care and Use of Laboratory Animals, Eighth Edition, and was approved by the University of Wisconsin School of Medicine and Public Health Animal Care and Use Committee.

### 2.1. *Animal subjects*

Ten young adult (9 month, 433.8 g [SD $\pm$ 35.75]) and 10 old (32 month, 531.2 g [SD $\pm$ 67.84]) male Fischer 344/Brown Norway rats were used in this research. The median life expectancy of the Fischer 344/Brown Norway rat is approximately 36 months.[29] One old rat expired during anaesthesia; thus data are reported for 10 young adult and 9 old rats.

### 2.2. *Surgical method*

Following anaesthesia with an intraperitoneal injection of sodium pentobarbital (70 mg/kg), the hypoglossal nerves were exposed bilaterally using a ventral approach under an operating microscope. Bipolar electrodes in a silicon nerve cuff were placed distal to the bifurcation of the whole hypoglossal nerve. The bifurcation of hypoglossal nerve was identified during placement of the cuff. In addition, identification of the bifurcation was further substantiated during the dissection of the medial branch of the hypoglossal nerve. Each nerve was tested for appropriate reaction to stimulation prior to data acquisition.

Two experimental conditions followed: (1) whole nerve stimulation and muscle contractile property recordings, and (2) isolated lateral branch recordings. That is, following whole nerve stimulation recordings as described below, the medial branch of the hypoglossal nerve was isolated and transected bilaterally using microscissors, leaving an intact lateral branch. Following a 45-min waiting period, the hypoglossal nerves were stimulated again, resulting in the isolated stimulation of the lateral branch of the hypoglossal nerve.