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Translational study on recurrent laryngeal nerve temperature susceptibility

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ABSTRACT

Background: Recurrent laryngeal nerve (RLN) injury is the most common and serious complication after thyroid surgery. However, little is known about the temperature threshold leading to RLN injury. In this study, we investigated threshold temperatures that cause RLN injury during thyroid surgery using continuous intraoperative neuromonitoring in swine models.

Methods: Four pigs weighing 30 to 40 kg were used for this study. We applied automatic periodic stimulation to the vagus nerve and dissected the RLN. The operative field was then filled with water at various temperatures (1.9°C to 87.4°C). The threshold temperature was defined as the temperature measured before filling the operative field that was associated with adverse events (latency increase of more than 10% or amplitude decrease of more than 50%). Loss of signal was defined as the electromyography (EMG) signal disappearing and not recovering during 30 min of observation.

Results: The low and high threshold temperatures were 2.5°C and 81.5°C, respectively. There were no adverse events at surrounding temperatures between 5.9°C and 77.5°C. The EMG signals in the RLNs exposed to the low threshold temperatures recovered, and there was no loss of signal. In contrast, the RLNs that showed adverse events at the high threshold temperatures showed loss of signal and no recovery of EMG signals.

Conclusions: The RLN was found to be resistant to cold injury, whereas surrounding temperatures above 81.5°C may cause permanent thermal injury to the RLN. The surrounding temperature should be controlled within the safe range during thyroid surgery to avoid RLN injury.

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Introduction

The susceptibility of human nerves to nonfreezing cold and to high temperatures has been documented for the sciatic, tibial, phrenic, facial nerves, as well as the central nervous system.[1-5] However, several aspects of the pathogenesis and recovery of thermal nerve injury remain unclear. For the recurrent laryngeal nerve (RLN), studies have documented sensitivity to the operating room temperature, salite irrigation of the surgical field, heat dissipation following ablation therapy, air pocket temperature during endoscopic procedures, and the heat emitted by endoscopic cameras.[6-8] Recent studies have led to recommendations that previous thyroid surgery procedures be modified to incorporate longer cooling times. Even so, a better understanding of the mechanisms underlying heat-induced RLN injury should assist in avoiding unnecessary damage.

Because of the importance of the problem, several protocols for studying temperature-induced nerve damage have been developed.[9,10] Currently, however, only one study of the causes of temperature-induced RLN dysfunction is available. A preliminary study by Wu *et al*. provided experimental evidence that 60°C is the critical temperature for RLN thermal injury.[11] However, the protocol used in that study did not take into account the dissipation of heat into tissues surrounding the area of impact. In this series of experiments on thermally induced RLN neuropathy, we therefore sought to develop and verify a temperature variation protocol that would allow us to explore the susceptibility and resistance of RLN to temperatures ranging from nonfreezing cold to high heat.

Materials and methods

Animal breeds

This study was approved by the Korea University Institutional Animal Care and Use Committee (Seoul, Korea) under protocol number KUIACUC-2014-170. Four pigs (race: Yorkshire-Landrace-Duroc, female piglets), weighing 30–40 kg, were used to evaluate the threshold leading to thermal RLN injury, by varying the surrounding temperature. All experiments were performed according to institutional guidelines that comply with national and international regulations for animal experiments.[12]

Induction and maintenance of anesthesia

This is a prospective *in vivo* pig model. The pigs were fasted for 12 h preoperatively and injected with intramuscular preanesthetic medication, with xylazine (Rompun; Bayer, Leverkusen, Germany) (1 mg/kg) and zolazepam/tiletamine (Zoletil; Virbac S.A., Carros, France) (7 mg/kg). Then the pigs were placed on an operating table in the supine position with their neck extended. The pigs were intravenously cannulated at the auricular vein and received continuous infusion of lactated Ringer's solution at 5 mL/kg/h during the operation. Muscle relaxants were avoided to prevent the EMG signal from being inhibited. The pigs were intubated with a 6-mm EMG endotracheal tube (Medtronic, Jacksonville, USA). The depth and angle of the contact between the electrode surface of endotracheal tube and the mucosa of the vocal cords were confirmed by the video laryngoscopy. In detail, the tube was placed with the middle of exposed electrodes (black line of the EMG tube) well in contact with true vocal cords under a direct laryngoscope. Tidal volume and respiratory rate were set at 8 mL/kg and 15 to 20 breaths/min, respectively.

Apparatus

The NIM 3.0 nerve monitoring system (Medtronic, Dublin, Ireland) and an automated periodic stimulation (APS, 2 mm; Medtronic, Dublin, Ireland) electrode were used for CIONM. The frequency, duration, and current of the APS were 1/s, 100 us, and 2 mA, respectively. A conventional monopolar stimulation probe (4 pulse/s, 100 us, 1 mA; Medtronic) was used for identification and intermittent stimulation of the RLN. For measuring the water temperature, an Intelligent Thermometer (YK-2001PH; Lutron, Taipei, Taiwan) was used.

Nerve exposure

We made a midline vertical cervical incision for exposure of the trachea, the thyroid glands, the RLN, and the vagus nerve. Bilateral RLNs and vagus nerves were identified visually, using a handheld stimulation probe, and then dissected free from the overlying soft tissue and fascia. After positioning the APS electrode on the vagus nerve, baselines of the amplitude and the latency of the evoked response were calibrated (Fig. 1).

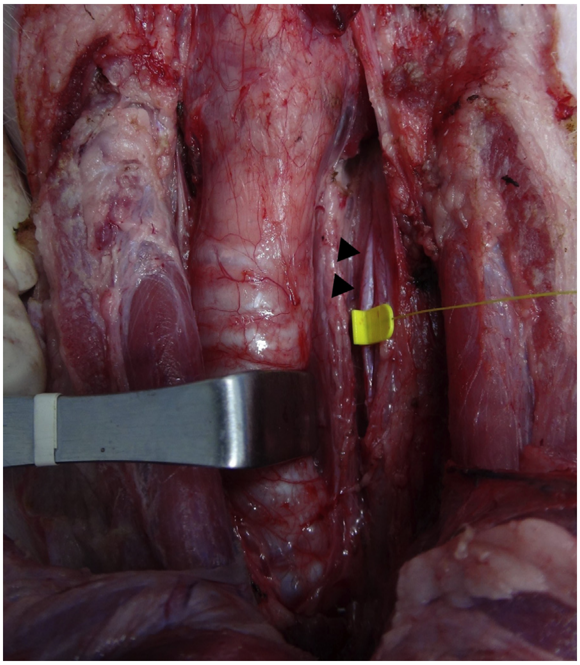

Fig. 1 – Surgical anatomy of the swine neck. The automatic periodic stimulation (APS) electrode was positioned on the left vagus nerve. (Color version of figure is available online.)