Development of an Attachable Endoscopic Nerve Stimulator for Intraoperative Neuromonitoring during Endoscopic or Robotic Thyroidectomy

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Abstract
We developed a simple attachable endoscopic nerve stimulator that can be connected to monopolar cauterization surgical instruments. This study on porcine models aimed to investigate the feasibility and efficacy of an attachable endoscopic nerve stimulator for intraoperative neuromonitoring (IONM) before application in humans. We evaluated the electromyography (EMG) amplitudes of 8 recurrent laryngeal nerves in 4 pigs with a conventional nerve probe and the attachable endoscopic nerve stimulator. The attachable endoscopic nerve stimulator was feasible and safe in all cases. There was no significant difference in the EMG amplitude of the recurrent laryngeal nerve among instruments (P = .429). The application of stimulating dissection with an attachable endoscopic nerve stimulator during endoscopic or robotic thyroidectomy with IONM is simple, convenient, and effective. It provides surgeons with real-time feedback of the EMG response during intermittent IONM. We believe that this novel device could be an essential guide and functional navigator for most surgeons, especially for less experienced ones.

Keywords
attachable nerve stimulator, endoscopy, robot, neuromonitoring, recurrent laryngeal nerve, thyroidectomy

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Remote approaches in thyroidectomy with endoscopes or robots have recently been introduced and used actively to decrease cosmetic problems and morbidity. Some studies reported temporary and persistent recurrent laryngeal nerve (RLN) palsy rates of 3.8% to 16% and 0% to 0.9%, respectively, in robotic thyroidectomy.¹⁻⁵ In studies comparing robotic surgery with open thyroidectomy, the rate of temporary RLN palsy was higher in robotic surgery than in open thyroidectomy (1.4% to 2.4% vs 0% to 0.7%).⁶ Endoscopic and robotic thyroidectomies are more likely than open thyroidectomy to have higher incidences of transient RLN palsy.

An intraoperative neuromonitoring (IONM) system can facilitate the identification of the RLN and prevent RLN injury during thyroidectomy.⁷ To identify the RLN with the IONM, the operation should be stopped, and the nerve stimulator should be used to stimulate the structure suspected to be the RLN. Because of the short length of the conventional nerve stimulator, it is difficult to use a nerve probe during endoscopic or robotic surgery. Additionally, repeated use of a nerve stimulator to identify nerves is a cumbersome procedure that lengthens the operation time. Thus, we developed an easily attachable endoscopic nerve stimulator that can connect to endoscopic or robotic instruments. The objective of this study is to investigate the feasibility and safety of using an endoscopic or robotic surgical instrument connected to an endoscopic nerve stimulator during IONM in porcine models before application to humans.

Materials and Methods
The protocol was approved by the Pusan National University Institutional Animal Care and Use Committee. The experiment was carried out with 8 RLNs in 4 pigs that underwent thyroidectomy. All pigs were intubated with standard reinforced electromyography (EMG) endotracheal
tubes (7.0 mm) under a nerve integrity monitor (NIM-Response 2.0; Medtronic Xomed, Jacksonville, Florida).

The EMG amplitudes of the 8 RLNs were measured with a conventional nerve stimulator and endoscopic or robotic surgical instruments connected with the attachable endoscopic nerve stimulator. The stimulus current was set at 3 mA with a frequency of 4 Hz.

Endoscopic and robotic surgical instruments are made with an insulator that does not conduct electricity. It is impossible to conduct electricity by attaching materials, such as magnets and forceps, as nerve stimulators on the surface of endoscopic and robotic instruments. Due to the characteristics of endoscopic or robotic surgery, instruments are used for electric cauterization because the surgeon’s hands cannot access the bleeding site directly. The attachable endoscopic nerve stimulator can be attached to a connecting pin of the endoscopic and robotic surgical instrument for monopolar cauterization. Endoscopic scissors, endoscopic forceps, robotic curved scissors, and robotic cautery hooks were connected to the attachable endoscopic nerve stimulator (Figures 1 and 2).

Statistical analyses were performed with Kruskal-Wallis test with SPSS 18.0 (IBM, Armonk, NY). $P < 0.05$ is considered significant.

**Results**

The EMG amplitude values of the 8 RLNs were analyzed (Table 1). There was no significant difference in the EMG amplitude of the RLNs measured with a conventional nerve stimulator and the surgical instruments ($P = .429$).

**Discussion**

Surgical structures are more difficult to identify during endoscopic or robotic surgery than during open surgery because of the difference in tactile sense and surgical exposure—thus, the relatively high risk of nerve injury in robotic surgery. Furthermore, a conventional nerve stimulator is designed for open surgery, so it is difficult to apply to endoscopic or robotic surgery because of its short length. It is inconvenient and time-consuming. A previously developed stimulating dissecting instrument that combined the function of surgical dissection and nerve stimulation could be affixed to 1 surgical instrument only. However, a novel attachable endoscopic nerve stimulator can be applied to endoscopic or robotic surgical monopolar cauterization instruments regardless of the shape of the instrument, according to the surgeon’s preference. It may provide the surgeon with easy and rapid identification of the RLN without having to change the surgical instrument during endoscopic or robotic thyroidectomy under IONM. There is no risk for injury during contact with surrounding surgical structures because it is insulated except for the connector pin and tip of the instrument.

There are some limitations. The metallic tip and connector pin of endoscopic and robotic surgical instruments are not insulated. If the surroundings of the tip of the surgical instrument touch other parts of the surgical field, the voltage at the tip of the surgical instrument could be decreased. So it cannot provide the appropriate voltage stimulation to identify a nerve. To overcome this limitation, the surgeon should be careful so that the surroundings of the tip of the surgical instrument do not touch other portions of the surgical field.
The endoscopic and robotic surgical instrument with an attachable endoscopic nerve stimulator can identify the real-time location and function of RLN during endoscopic and robotic thyroid surgery. These may prevent nerve damage by nerve traction even if continuous IONM is not used. We suggest that our device can help to identify not only the RLN but also the external branch of the superior laryngeal nerve. It could be an essential guide and

Table 1. Comparison of Stimulating EMG Amplitudes of the RLN as Recorded with Various Endoscopic Surgical Instruments with an Attachable Nerve Stimulator.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Pig 1 Right</th>
<th>Pig 1 Left</th>
<th>Pig 2 Right</th>
<th>Pig 2 Left</th>
<th>Pig 3 Right</th>
<th>Pig 3 Left</th>
<th>Pig 4 Right</th>
<th>Pig 4 Left</th>
<th>Mean ± SD*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nerve stimulator</td>
<td>295</td>
<td>138</td>
<td>217</td>
<td>266</td>
<td>214</td>
<td>213</td>
<td>312</td>
<td>208</td>
<td>232.9 ± 55.9</td>
</tr>
<tr>
<td>Endoscopic scissors</td>
<td>288</td>
<td>132</td>
<td>287</td>
<td>311</td>
<td>298</td>
<td>213</td>
<td>344</td>
<td>216</td>
<td>261.1 ± 68.8</td>
</tr>
<tr>
<td>Endoscopic forceps</td>
<td>293</td>
<td>143</td>
<td>267</td>
<td>251</td>
<td>290</td>
<td>203</td>
<td>333</td>
<td>221</td>
<td>250.1 ± 59.9</td>
</tr>
<tr>
<td>Robotic curved scissors</td>
<td>361</td>
<td>142</td>
<td>237</td>
<td>267</td>
<td>305</td>
<td>214</td>
<td>322</td>
<td>212</td>
<td>257.5 ± 70.7</td>
</tr>
<tr>
<td>Robotic cauter hook</td>
<td>323</td>
<td>149</td>
<td>300</td>
<td>299</td>
<td>327</td>
<td>201</td>
<td>329</td>
<td>230</td>
<td>269.8 ± 67.9</td>
</tr>
</tbody>
</table>

Abbreviations: EMG, electromyography; RLN, recurrent laryngeal nerve. *P = .429.
functional navigator for most endoscopic and robotic surgeons, especially for less experienced surgeons. It may also be applicable in other surgical procedures, such as thoracic or spine surgery, to identify motor nerves.

**Conclusion**

The development of an attachable endoscopic nerve stimulator for stimulating surgical dissection during endoscopic or robotic thyroid surgery provides a simple, convenient, and effective method for IONM. Our device can provide surgeons with real-time feedback of the EMG response of the RLN during endoscopic or robotic thyroid surgery with intermittent IONM.

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**Author Contributions**

**Eui-Suk Sung,** analysis and interpretation of data, writing of draft, final approval, agreement; **Jin-Choon Lee,** acquisition and interpretation of data, article revision, final approval, agreement; **Seok Hyun Kim,** acquisition and interpretation of data, article revision, final approval, agreement; **Sung-Chan Shin,** acquisition of data, article revision, final approval, agreement; **Da-Woon Jung,** interpretation of data, article revision, final approval, agreement; **Byung-Joo Lee,** conception and design of the study, interpretation of data, article revision, final approval, agreement.

**Disclosures**

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**References**


