Hoarseness as a complication during anterior cervical spine surgery is a well-known problem.\textsuperscript{1-10} It is caused by palsy of 1 or both of the recurrent laryngeal nerves (RLNP). The unilateral RLNP with a paramedian position of the vocal cord is mostly expressed clinically by dysphonia. Other reported symptoms are aspiration and dysphagia.\textsuperscript{9} However, the paralysis may be clinically silent. The clinical picture of bilateral RLNP with the typical position of the vocal cords corresponds most frequently to a high-level dyspnea with inspiratory stridor. In earlier studies the unilateral RLNP was reported to be the most frequent nerve complication during an anterior approach to the cervical spine.\textsuperscript{11-13} The incidence of asymptomatic RLNP in a right-sided approach was performed were examined postoperatively with indirect laryngoscopy to evaluate the status of the vocal cords. All patients had a left-sided approach but 1 group (A, 149 patients) was operated on with an additional reduction of endotracheal cuff pressure to below 20 mm Hg. In 93 patients we could not reduce the cuff pressure. This group served as a control group (B). Both groups were compared with a historic control group with a right-sided approach and no cuff pressure reduction. In cases of vocal cord malfunction a follow-up examination was done 3 months later.

RESULTS: Group A (low cuff pressure) had a total rate of persisting symptomatic and asymptomatic RLNP of 1.3\% and group B had a rate of 6.5\% (normal cuff pressure). Compared with the historic study (\(N = 120\)) with a right-sided approach and a total rate of persisting RLNP of 13.3\% in the left-sided approach, a marked reduction to 6.5\% and 1.3\% with an additional reduction of cuff pressure was seen.

CONCLUSION: The left-sided approach in anterior cervical spine surgery reduces the incidence of postoperative and permanent RLNP significantly. Endotracheal cuff pressure reduction used additionally decreases the rate of RLNP even more. These results indicate that anterior cervical spine surgery should be performed with a left-sided approach and, if possible, with an additional reduction of the endotracheal cuff pressure while the retractors are inserted.

KEY WORDS: Complications in spine surgery, Endotracheal cuff pressure, Hoarseness, Left-sided approach, Recurrent laryngeal nerve-cervical spine surgery

Abbreviations: RLN, recurrent laryngeal nerve; RLNP, recurrent laryngeal nerve palsy

How to Reduce Recurrent Laryngeal Nerve Palsy in Anterior Cervical Spine Surgery: A Prospective Observational Study

BACKGROUND: Recurrent laryngeal nerve palsy (RLNP) occurs as a complication during anterior cervical spine surgery. In 2005 the authors demonstrated the high incidence of asymptomatic RLNP in a right-sided approach.

OBJECTIVE: This follow-up prospective observational study was designed to test 2 options said to reduce the rate of RLNP: reduced endotracheal cuff pressure and sinistral approach.

METHODS: Two hundred forty-two patients in whom anterior cervical spine surgery was performed were examined postoperatively with indirect laryngoscopy to evaluate the status of the vocal cords. All patients had a left-sided approach but 1 group (A, 149 patients) was operated on with an additional reduction of endotracheal cuff pressure to below 20 mm Hg. In 93 patients we could not reduce the cuff pressure. This group served as a control group (B). Both groups were compared with a historic control group with a right-sided approach and no cuff pressure reduction. In cases of vocal cord malfunction a follow-up examination was done 3 months later.

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The recurrent laryngeal nerve will usually not be surgically exposed during anterior cervical spine surgery.20 The nerve has a variant course and is a thin structure (1-3 mm) so the surgeon may have difficulties identifying and exposing the nerve.21 Recently there have been some reports on monitoring of the RLN during spine surgery, such as vocal cord electromyographic monitoring,8 although the precise criteria for intervention remain unclear. Two possibly important aspects from the literature should be considered. First, the anatomically less exposed course of the left recurrent laryngeal nerve22 and second, the role of the endotracheal cuff pressure in the pathomechanism of harming the recurrent laryngeal nerve.23

Therefore a prospective study was initiated to determine the influence of these 2 factors.

PATIENTS AND METHODS

Of 258 patients who underwent anterior cervical spine surgery such as anterior cervical discectomy, corporectomy, and osteosynthetic fusion procedures in our department, an indirect laryngoscopy was done in 242 patients (161 males and 81 females) (historic group C, 80 males/40 females), who were included in the study to evaluate the postoperative status of the vocal cords. The variance of the average age (50.8 and 52.3) of all groups was statistically irrelevant. Our previous study indicated that a preoperative examination was only necessary to exclude an impairment of the vocal cords in cases with a history of thyroid or anterior cervical spine surgery.19 Before surgery all patients were informed that a laryngoscopy would be performed. In our historic study we demonstrated a high rate of clinically asymptomatic RLNP. Because a silent RLNP constitutes a certain risk for the patient in any later surgery (anterior cervical spine/thyroidectomy), we believe that it is not unethical to test with laryngoscopy on a routine basis.

From May 2005 to August 2007 all patients were operated on with a left-sided approach. In 149 cases (group A) the endotracheal cuff pressure of the intubation tube could be reduced below 20 mm Hg. In 93 cases (group B) it was impossible to reduce the cuff pressure for anesthesiological reasons or was forgotten. In this way a “control group” was created that allowed a comparison of the effects of left-sided approach only vs the added effect of cuff pressure reduction. These 2 groups could be compared with a historic control group (group C) from the former prospective study group (Jung and Schramm) of 120 patients that were operated on with a right-sided approach.

The examination period covers 27 months and the distribution of neurosurgical procedures was 107 anterior cervical discectomies without fusion (methacrylate spacer), 131 osteosynthetic fusions, and 20 anterior cervical discectomies with an implantation of a disc prosthesis. Of the surgical procedures 50.4% were multilevel operations with larger exposure of the cervical spine (see Table 1). The distribution of the various diagnoses, types of operations, and extents of the operations did not show any differences among the 3 groups (see Table 1). We could obtain a 95.8% follow-up after 3 months. In 15 patients with preoperative paraparesis or tetraparesis we could not obtain a postoperative laryngoscopy because of early transfer to a specialized rehabilitation center for tetra/paraplegic patients or prolonged intensive care unit treatment. One patient with an asymptomatic RLNP came from abroad and could not be contacted for follow-up examination. The surgical procedures were done by 8 different neurosurgeons and neurosurgeons in training. The overall complication rate was 4.6% including all well-known major and minor complications (see Table 2).

RESULTS

One patient with previous carbon monoxide intoxication had a preoperative, symptomatic unilateral RLNP in the laryngoscopy. This patient experienced no deterioration in the postoperative laryngoscopy. All patients (N = 242) underwent a postoperative laryngoscopy in the early postoperative period (between the third and seventh days). In group A (left-sided approach plus reduced endotracheal cuff pressure) there were 4 new unilateral palsies/paresis (2.7%) of the recurrent laryngeal nerve (see Table 3). Three of them were asymptomatic and 1 patient was discovered with hoarseness. All of them had a 3-month follow-up examination. One patient still had a clinically relevant hoarseness. Another patient had an asymptomatic RLNP. That equals a 1.3% follow-up rate of RLNP in group A. In group B (left-sided approach only) we discovered 13 new unilateral palsies/paresis (14.0%) (see Table 4). Four were clinically symptomatic in the initial examination (4.3%). In the follow-up examination 2 patients had persisting hoarseness (2.2%) and 4 patients (4.3%) were clinically asymptomatic but had RLNP. That equals a 6.5% follow-up rate of RLNP in group B. Thus, the addition of cuff pressure reduction lowered the late RLNP rate from 6.5% to 1.3% for left-sided approaches. Looking at

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>A</th>
<th>B</th>
<th>Total</th>
<th>Operation</th>
<th>A</th>
<th>B</th>
<th>Total</th>
<th>Extent</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft disc</td>
<td>60</td>
<td>36</td>
<td>96</td>
<td>Plate-fusion</td>
<td>84</td>
<td>47</td>
<td>131</td>
<td>One level</td>
<td>128</td>
</tr>
<tr>
<td>Stenosis</td>
<td>67</td>
<td>47</td>
<td>114</td>
<td>Methacrylate-interposition</td>
<td>63</td>
<td>44</td>
<td>107</td>
<td>Two levels</td>
<td>103</td>
</tr>
<tr>
<td>Fracture</td>
<td>28</td>
<td>14</td>
<td>42</td>
<td>Disk-prosthesis</td>
<td>12</td>
<td>8</td>
<td>20</td>
<td>Three levels</td>
<td>27</td>
</tr>
<tr>
<td>Inflammation</td>
<td>4</td>
<td>2</td>
<td>6</td>
<td>Total</td>
<td>159</td>
<td>99</td>
<td>258</td>
<td>Total</td>
<td>258</td>
</tr>
</tbody>
</table>

TABLE 1. Distribution of the Various Diagnoses, Operations, and Extents of the Operations between the Groups and Total
symptomatic cases only, the rate of permanent hoarseness is also markedly reduced from 2.2% to 0.7%.

Quoting the results of the previous prospective study (Jung et al19) for comparison the early RLNP rate was 24.1% (8.3% symptomatic) and the follow-up RLNP rate was 13.3%. Use of this historic group for comparison shows that the left-sided approach significantly lowers the RLNP rate from 13.3% to 6.5% and the additional use of cuff pressure reduction dramatically improves the rate to 1.3%.

In total we counted 13.3% permanent RLNP in group C (see Table 5). That results in a reduction of RLNP to 6.5% in the left-sided approach and to 1.3% in the left-sided approach with an additional reduction of the endotracheal cuff pressure.

TABLE 2. Surgical Complications in Study Group N = 258

<table>
<thead>
<tr>
<th>Complication</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cerebrospinal fluid leakage</td>
<td>1</td>
</tr>
<tr>
<td>Neurological impairment</td>
<td>3</td>
</tr>
<tr>
<td>Malposition screws/plates</td>
<td>4</td>
</tr>
<tr>
<td>Hemorrhage</td>
<td>3</td>
</tr>
<tr>
<td>Infection</td>
<td>1</td>
</tr>
<tr>
<td>Extended dysphagia</td>
<td>1</td>
</tr>
</tbody>
</table>

In cases of early postoperative decreased motion of the vocal cord the results of follow-up laryngoscopy were always normal in all 3 groups. We also tested whether among the 8 surgeons the risk for RLNP was increased for a specific surgeon. That was not the case. There was no correlation between level or extent of operation and RLNP.

DISCUSSION

Damage to the RLN is a well-known problem in anterior cervical spine and thyroid surgery. In contrast to thyroid surgeons, for whom it is standard procedure to expose the recurrent laryngeal nerve and monitor more frequently,24-27 spine surgeons do not use these procedures, according to the standard textbooks.20,28,29 Various mechanisms of trauma cause palsy. It may be related to indirect intraoperative injury to the nerve, entrapment of the nerve between retractor blades and endotracheal tube (especially the inflated cuff of the endotracheal tube),30,31 or traction injury of the nerve.7,17,32

The endotracheal tube alone can be a cause for RLNP and is said to account for 11.2% to 7.5% of all vocal cord paralyses.33-35 Spontaneous preoperative RLNP (possibly asymptomatic) may exist, as in our historic series in 1.6%, or in the only other 2 series that prospectively examined all patients (Francois et al,5 1.5%; Curley et al, 1.6% of 1900 patients). Not all postoperative RLNP

TABLE 3. Status of the RLN at Various Times of Study Group A With Left-Sided Approach and Reduced Endotracheal Cuff Pressure Subdivided for the Groups With and Without Hoarseness (% in Parentheses), N = 149a

<table>
<thead>
<tr>
<th>Early Postoperative</th>
<th>3-Month Follow-Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total No. (%)</td>
<td>Paresis (%)</td>
</tr>
<tr>
<td>RLNP with hoarseness</td>
<td>1 (0.7)</td>
</tr>
<tr>
<td>RLNP without hoarseness</td>
<td>3 (2.0)</td>
</tr>
<tr>
<td>No. (%) of total group A</td>
<td>4 (2.7)</td>
</tr>
</tbody>
</table>

a RLN, recurrent laryngeal nerve; RLNP, recurrent laryngeal nerve palsy.

b Decreased motion of the vocal cord.

c Standstill of the vocal cord.

TABLE 4. Status of the RLN at Various Times of Study Group B With Left-Sided Approach Only Subdivided for the Groups With and Without Hoarseness (% in Parentheses), N = 93

<table>
<thead>
<tr>
<th>Early Postoperative</th>
<th>3-Month Follow-Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total No. (%)</td>
<td>Paresis (%)</td>
</tr>
<tr>
<td>RLNPc with hoarseness</td>
<td>4 (4.3)</td>
</tr>
<tr>
<td>RLNP without hoarseness</td>
<td>9 (9.7)</td>
</tr>
<tr>
<td>No. (%) of total group B</td>
<td>13 (14.0)</td>
</tr>
</tbody>
</table>

d Decreased motion of the vocal cord.

e Standstill of the vocal cord.

f RLNP, recurrent laryngeal nerve palsy.
cases are therefore caused by manipulation of the neurosurgeons. Because of anatomic circumstances, the trauma to the nerve is the most likely in a right-sided (in cervical spine surgery most commonly) approach, although not all authors could confirm this hypothesis.2 The right-sided nerve is shorter and has a more oblique course than the left RLN.36 The traction interrupts the perineural blood flow and traumatizes the nerve.32 Other studies demonstrated the possible influence of endotracheal tube cuff pressure on a recurrent laryngeal nerve injury.1,8,37 The increase of cuff pressure caused by retractors reduces on 1 side the mucosal blood flow and on the other side may trap the nerve itself. As a result of these studies deflation and reinflation of the cuff of the endotracheal tube can reduce the iatrogenic trauma to the RLN, as demonstrated by Apfelbaum and colleagues.1 We demonstrated that a reduction of the endotracheal cuff pressure below 20 mm Hg when inserting the retractor instrumentation reduces the damage to the RLN. In thyroid surgery the RLN was found mostly damaged because of the ligature of the inferior thyroid artery or unspecified traction of the surrounding tissue.38 Other important factors that affect the incidence rate of RLNP have been identified as the extent and type of the operation and, especially in patients with carcinoma, the experience of the surgeon.38,39 We could not find a correlation between the extent and type of operation in the 120 patients of the historic study (Jung et al19) or in the 242 patients of the present study, nor did it depend on the experience of the surgeon. Earlier studies show that the routinely practiced identification or exposure of the RLN reduces the risk for RLNP significantly.40 Exact data about the significance of the introduction of the RLN exposure does not exist because other cofactors reduced the incidence of RLNP in the period from 1950 to 1960 from approximately 20% to 2 to 4% in thyroid surgery.41-43 In our study we demonstrate that the left-sided approach reduces the risk of permanent RLNP in comparison with the right-sided approach from 13.3% to 6.5%. No other previous studies have compared the 2 approaches. The additional reduction of cuff pressure of the endotracheal tube below 20 mm Hg reduces the rate of a permanent RLNP to 1.3%. No other study can be compared with our findings because a similar study design has not been used. The rate of permanent hoarseness (2.2%) in group B is equivalent to earlier reported findings.4,5,7 The rate of permanent hoarseness (0.7%) in group A is lower than in earlier findings.

The general trend to small incisions, at least in disk surgery, leads to possibly more blind retraction of the tissue. This especially affects the right recurrent laryngeal nerve as demonstrated in cadaver preparations.32 So it may be prudent not to stress the minimalistic attitude during the approach but to perform an adequate exposure in the soft tissue layers between the neurovascular bundle and the thyroid-esophagus soft tissue mass.

From these findings and results one can draw the conclusion that the left-sided approach to the anterior cervical spine is safer regarding hoarseness and asymptomatic recurrent laryngeal nerve palsy. Furthermore, the reduction of the cuff pressure of the endotracheal tube—if possible—results in an enhanced reduction of postoperative hoarseness as well as asymptomatic RLN palsy. Therefore, it appears prudent to change the policy of the approach in anterior cervical spine surgery, as we have done already in our department.

By direct laryngoscopy we found again a higher initial rate of asymptomatic RLNP especially in group B (group A, 2.0%; group B, 9.7%) than quoted in the literature, although the rate was much lower than in our historic group that was operated on from the right side (15.9%). The recovery rate of the RLN is usually reported to be relatively good (ie, approximately 80%, Morpeth and Williams5), but nearly all authors only performed laryngoscopy in hoarse patients, presumably missing RLNP in cases without hoarseness. We confirmed that a decreased motion of the vocal cord (ie, paresis but no palsy) never led to permanent hoarseness.

With these results we need to re-discuss our initial demand (Jung et al19) that spine surgeons should consider learning routine exposure of the RLN. It might be enough to use the left-sided approach with an additional reduction of the endotracheal cuff pressure. We examined all patients who have a higher risk of damage of the RLN, as in cervical reoperation, enlarged thyroid, or status after thyroid surgery with a preoperative laryngoscopy to avoid exposure on the healthy side contralateral to an already damaged RLN. The same caution should be applied in cases of preexisting hoarseness. In that way we found the patient with carbon monoxide intoxication and clinically apparent hoarseness. This appears useful because a danger of permanent hoarseness or dyspnea exists.

### Table 5: Status of the RLN at Various Times of Historic Group C (N = 120) Subdivided for the Groups With And Without Hoarseness (% in Parentheses), Right-Sided Approach (Adapted from Jung et al19 With Permission)

<table>
<thead>
<tr>
<th></th>
<th>Early Postoperative</th>
<th>3-Month Follow-Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. (%)</td>
<td>Total No. (%)</td>
<td>Paralysis No. (%)</td>
</tr>
<tr>
<td>RLNP with hoarseness</td>
<td>10 (8.3)</td>
<td>0</td>
</tr>
<tr>
<td>RLNP without hoarseness</td>
<td>19 (15.9)</td>
<td>4 (3.3)</td>
</tr>
<tr>
<td>No. (%) of total group C</td>
<td>29 (24.2)</td>
<td>4 (3.3)</td>
</tr>
</tbody>
</table>

- RLNP: recurrent laryngeal nerve palsy.
- a Decreased motion of the vocal cord.
- b Standstill of the vocal cord.

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in cases of undetected contralateral recurrent laryngeal nerve palsy in patients with earlier neck surgery. One can imagine that an additional trauma to the ipsilateral RLN leads to bilateral vocal cord palsy with problems like severe inspiratory stridor, dysphasia with aspiration, aphony, or respiratory disorder with the urgent need of a respirator, intubation, or tracheotomy. A pre-operative laryngoscopy is certainly advisable in risky cases.

Other authors described that precautions like observing and deflating/reinflating of the cuff could become a standard procedure, especially in longer lasting, ie, larger surgeries. Duration of surgery, multilevel exposure, and low-level exposure were found to be associated with higher risk by Jellish et al and Apfelbaum et al. We could not confirm this correlation between multilevel exposure and injury to the nerve in this study.

Permanent electromyographic monitoring of the posterior laryngeal muscles could not avoid or determine an injury to the nerve. Several authors have reviewed electrophysiological detection and monitoring in the RLN, but it has also been pointed out that a “reliable statement” about postoperative RLNP is not possible and that the sensitivity was only 70% (Stremmel et al). In another series with monitoring transient paresis were not decreased (10.7% vs 9.7%), but permanent RLNP decreased from 3.0% to 1.8%.

**Limitations of This Paper**

Although it has previously been demonstrated that reduced cuff pressure alone and similarly left-sided approach alone lead to reduced RLNP, this is the first study demonstrating further reduction of RLNP, in particular, in clinically unapparent RLNP; although perfect statistical proof was impossible because of the low numbers.

One could argue that the random cases where the cuff pressure could not be held low and who thus could not be in the low-cuff-pressure group could introduce a relevant medical bias and make the control group unsuitable. However, because no medical reasons were detected as to why some patients ended up in the high-pressure group, we believe that it is unlikely that a relevant medical bias was introduced.

**CONCLUSIONS**

Asymptomatic RLNP is more frequent than symptomatic RLNP with hoarseness. The left-sided approach reduces the rate of symptomatic and asymptomatic RLNP and the additional reduction of the cuff pressure of the endotracheal tube results in an additional marked reduction of early and permanent RLNP. The level or extent of the operation was not predictive for the nerve injury. No correlation to 1 specific surgeon was found. In cases of decreased motion of the vocal cord in the early postoperative examination the patients always experienced a *restitutio ad integrum*.

These results show some evidence or a trend that anterior cervical spine surgery may lead to lower RLNP rates when done with a left-sided approach and reduced cuff pressure below 20 mm Hg, although it was not statistically proven.

**Disclosure**

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

**REFERENCES**

Author Query

AQ 1: Original Table 5 has been renumbered as Table 2, because it was cited next following Table 1. Tables and figures are numbered in the order in which they first appear in the text. Please check to ensure accuracy.

AQ 2: Okay to cite Table 3 (originally Table 2) here? All tables and figures must be called out in the text. If not, please indicate where this table should be cited.

AQ 3: Okay to cite Table 4 (originally Table 3) here? All tables and figures must be called out in the text. If not, please indicate where this table should be cited.

AQ 4: Throughout, where authors have been cited without the reference number, the reference number has been added. Please verify the accuracy of these additions.

AQ 5: Okay to cite Table 5 (originally Table 4) here in the text. All figures and tables must be called out in the text. If not, please indicate where this table should be cited.

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AQ 7: Please confirm the Disclosure statement.