Optic nerve compression by normal carotid artery in patients with normal tension glaucoma

N Ogata, M Imaizumi, H Kurokawa, M Arichi, M Matsumura

Aim: To determine whether compression of the optic nerve by the intracranial carotid artery (ICA) can be a causative factor of normal tension glaucoma (NTG).

Methods: The medical records of 103 eyes of 54 Japanese patients with NTG and 104 eyes of 52 age matched control patients were reviewed. The neuroradiological findings of magnetic resonance images (MRI) were evaluated to determine the relation between the optic nerve and ICA. The clinical characteristics and general medical conditions, such as diabetes and systemic hypertension, were also compared between the two groups.

Results: The prevalence of optic nerve compression by the ICA in patients with NTG was 49.5%, which was significantly higher than that in control group with 34.6% (p = 0.035). Bilateral compression of the optic nerve was detected in 22 patients with NTG (40.7%), and this was also significantly higher (p = 0.029) than that in the control group (11 patients, 21.2%). In the NTG group, eyes with cup/disc ratio (C/D ratio) \( \geq 0.7 \) showed a higher percentage of compression (52.6%) compared with eyes with C/D ratio of < 0.7 (12.5%; p = 0.042). The presence of diabetes and hypertension did not affect the incidence of optic nerve compression by ICA significantly.

Conclusions: The significantly higher percentage of NTG patients who had optic nerve compression by the ICA suggests that compression of the optic nerve by ICA may be a possible causative factor or a risk factor for optic nerve damage in some patients with NTG.

PATIENTS AND METHODS

This study was conducted to conform to the tenets of the Declaration of Helsinki, and informed consent was obtained from all patients after an explanation of the purpose and procedures of the study.

Abbreviations: C/D ratio, cup/disc ratio; ICA, intracranial carotid artery; MRI, magnetic resonance imaging; NTG, normal tension glaucoma
The visual acuity, optic disc head cupping, and laboratory tests for diabetes mellitus and systemic hypertension were determined for all patients diagnosed with NTG. All of the patients had normal findings for complete blood cell counts, serological test for syphilis, and sedimentation rate.

The control group was made up of 104 eyes of 52 age matched patients (22 men and 30 women, ages 41–88 years; average 68.0 (SD 14) years). These patients had consulted the Department of Internal Medicine in Saiseikai Izuo Hospital and had undergone MRI for a screening checking up. None of the control patients had a known ocular or neurological condition that might affect the visual pathways before the imaging. In addition, dilated ocular evaluations showed no signs of visual pathway disease.

MRI (Philips Co, Gyo Scan ACS-NT PT 3000) was performed at the initial examination, and from our experience, T1 weighted MRI sequences acquired in the coronal plane were taken as they were the optimal images to evaluate the anatomical relation between the intracranial optic nerve and the ICA. Radiological analysis was made by two experienced radiologists who were informed of the age and sex but were masked as to whether the patient was in the NTG or control group.

The relation between the optic nerve and the adjacent ICA was designated by the following grading scheme: grade 0, no contact or contact but without distortion of the optic nerve contour (contact but no compression); grade 1, contact with slight distortion of the optic nerve contour (slight compression); grade 2, contact with moderate or severe distortion of the optic nerve contour (moderate to severe compression; fig 1).

The medical records and MRI evaluation of all patients were reviewed. Categorical data were summarised as percentages, and statistical analysis of the MRI evaluations between groups was compared with \( \chi^2 \) tests. \( p \) Values less than 0.05 were considered to be significant.

**RESULTS**

**NTG versus control**

Of the 103 eyes of 54 patients with NTG, compression of the optic nerve was observed in 51 (49.5%) of the eyes and not observed in 52 (50.5%) of the eyes. In the 51 eyes with optic nerve compression, 33 eyes were classified as grade 1 (64.7%) and 18 eyes as grade 2 (35.3%). In the 104 eyes of 52 control patients, compression was observed in 36 eyes (34.6%) and not observed in 68 eyes (65.4%). In the 36 eyes with optic nerve compression, 22 eyes were classified as grade 1 (21.2%) and 14 eyes as grade 2 (13.4%). The percentage of eyes with compression of the optic nerve was significantly higher in the eyes with NTG than that in the control group (\( \chi^2 = 4.4, p = 0.035 \)). The percentage of eyes with grade 2 compression in the NTG group was not significantly higher than that in control group (\( \chi^2 = 1.6, p = 0.20 \)).

![Figure 1](https://example.com/figure1.png)

**Figure 1** The grading scheme of T1 weighted MRI sequences acquired in the coronal plane. The relation between the optic nerve and the adjacent intracranial carotid artery (ICA) was classified into three grades as described in text. Top image shows no optic nerve compression and was graded as 0. Middle image shows slight optic nerve compression and was graded as 1.0. Bottom image shows marked optic nerve compression and was graded as 2.0.

![Figure 2](https://example.com/figure2.png)

**Figure 2** Frequency of optic nerve compression by ICA. Of the 103 eyes of 54 patients with NTG, compression of the optic nerve was observed in 51 eyes (49.5%) and not observed in 52 (50.5%) of the eyes. In the 51 eyes with optic nerve compression, 33 eyes were classified as grade 1 (64.7%) and 18 eyes as grade 2 (35.3%). In the 104 eyes of 52 control patients, compression was observed in 36 eyes (34.6%) and not observed in 68 eyes (65.4%). In the 36 eyes with optic nerve compression, 22 eyes were classified as grade 1 (21.2%) and 14 eyes as grade 2 (13.4%). The percentage of eyes with compression of the optic nerve was significantly higher in the eyes with NTG than that in the control group (\( \chi^2 = 4.4, p = 0.035 \)). The percentage of eyes with grade 2 compression in the NTG group was not significantly higher than that in control group (\( \chi^2 = 1.6, p = 0.20 \)).

### Table 1 The frequency of the compression of optic nerve by ICA

<table>
<thead>
<tr>
<th>Number of patients</th>
<th>Number of eyes</th>
<th>No Compression Grade 0 (%)</th>
<th>Compression (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>52</td>
<td>104</td>
<td>68 (65.4%)</td>
</tr>
<tr>
<td>NTG</td>
<td>54</td>
<td>103</td>
<td>52 (50.5%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Grade 1</th>
<th>Grade 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>22 (61.1%)</td>
<td>14 (38.9%)</td>
</tr>
<tr>
<td>NTG</td>
<td>33 (64.7%)</td>
<td>18 (35.3%)</td>
</tr>
</tbody>
</table>

NTG, normal tension glaucoma.
and 16 eyes as grade 2 (35.3%). In the 104 eyes of 52 control patients, compression was observed in 36 eyes (34.6%) and not observed in 68 eyes (65.4%). In the 36 eyes with optic nerve compression, 22 eyes were classified as grade 1 (61.1%) and 14 eyes as grade 2 (38.9%; table 1). The percentage of eyes with compression of the optic nerve was significantly higher in the eyes with NTG than that in the control group ($\chi^2 = 4.4, p = 0.035$; fig 2). The percentage of eyes with grade 2 compression was not significantly higher in the NTG group than that in the control group ($\chi^2 = 1.6, p = 0.20$; fig 2).

In the three patients with unilateral NTG, compression was observed in one of the fellow eyes and not observed in two eyes. Because the number of eyes in the unilateral NTG group was small, it was difficult to compare the frequency of the optic nerve compression to the other groups statistically.

### Bilateral and unilateral compression

In the 54 patients with NTG, 22 patients (40.7%) had bilateral compression of the optic nerves by the ICA, nine patients (16.7%) had unilateral compression, and optic nerve compression was not found in either eye in 23 patients (42.6%). Of the 52 patients in the control group, only 11 patients had bilateral optic nerve compression (21.2%), 14 patients (26.9%) had unilateral compression, and 27 patients (51.9%) had no compression. The prevalence of bilateral optic nerve compression was significantly higher in NTG group than that in the control group ($\chi^2 = 4.74, p = 0.029$, table 2).

### Optic disc cupping

In the 103 eyes in the NTG group, there were 95 eyes (93.2%) with a C/D ratio $\geq 0.7$, and in this group, there were 50 eyes (52.6%) with compression of the optic nerve by the ICA. Of the eight eyes with C/D ratio $\leq 0.7$, only one eye (12.5%) had a compression of the optic nerve by the ICA. The higher percentage of eyes with C/D ratio $< 0.7$ who showed compression was statistically different from eyes with C/D ratio $\geq 0.7$ ($\chi^2 = 5.7, p = 0.017$; and $\chi^2 = 4.1, p = 0.042$ with Yates’s correction). None of the eyes in the control group had a C/D ratio $\geq 0.7$ (table 3, fig 3).

### Patients with diabetes mellitus

There were 34 eyes of 17 patients with diabetes mellitus (32.7%) in the control group, and of these, optic nerve compression was observed in 11 eyes (32.4%) and not observed in 23 eyes (67.6%). Of the 70 eyes of 35 patients without diabetes in the control group, compression was observed in 25 eyes (35.7%) and compression was not observed in 45 eyes (64.3%). The difference in the percentage of eyes with optic nerve compression in the two groups was not significantly different ($\chi^2 = 0.11, p = 0.32$, table 3).

In NTG group, there were 14 eyes of seven patients with diabetes mellitus (13.6%) and 89 eyes of 47 patients without diabetes mellitus (86.4%). Of the 14 eyes of the NTG patients with diabetes, compression of the optic nerve was observed in four eyes (36.4%) and not observed in 10 eyes (63.6%). Of the 89 eyes of non-diabetic patients in the NTG group, compression was observed in 47 eyes (52.8%) and not observed in 42 eyes (47.9%). The difference between patients with and without diabetes in NTG was not significant ($\chi^2 = 1.96, p = 0.16$, table 4).

### Patients with systemic hypertension

In the controls, there were 30 patients with hypertension (57.7%) and 22 patients (42.3%) without hypertension. Of the 60 eyes of 30 patients with hypertension, compression was observed in 22 eyes (36.7%) and not observed in 38 eyes (63.3%), and of the 44 eyes of 22 patients without hypertension, compression was observed in 14 eyes (31.8%) and not observed in 30 eyes (68.2%). The difference in the percentage of eyes with compression in the control group with or without hypertension was not significantly different ($\chi^2 = 0.26, p = 0.61$, table 3).

In NTG group, there were 32 eyes of 17 patients with hypertension (31.5%) and 71 eyes of 37 patients without hypertension (68.5%). Of the 32 eyes of patients with hypertension, optic nerve compression was observed in 15 eyes (46.9%) and not observed in 17 eyes (53.1%), and of the 71 eyes of patients without hypertension, compression was observed in 36 eyes (50.7%) and not observed in 35 eyes (49.3%). The difference in the percentage of eyes with compression between patients with and without hypertension in the NTG group was not significant ($\chi^2 = 0.16, p = 0.69$, table 4).

### DISCUSSION

A compression of the optic nerve by normal carotid arteries has been suggested to be a possible cause of visual field defects in patients with optic neuropathy and with NTG. Jacobson et al. used MRI to show that an anatomic compression of the intracranial optic nerve by the ICA occurred relatively frequently in asymptomatic patients; contact of one or both optic nerves in 70 of 100 asymptomatic patients; bilateral compression in 12 of 100; and unilateral compression in five of 100 asymptomatic patients. Although we did not classify cases that only showed a contact of the optic nerve by the ICA into the compression group, we found an anatomic compression of the optic nerve by ICA in 36 eyes of 104 optic nerves (34.6%) in 52 control patients. Of these, only 11 patients showed bilateral compression (21.2%) and 19 patients (26.9%) showed unilateral compression. This ratio of optic nerve compression is higher than that

<table>
<thead>
<tr>
<th>Table 2 Frequency of bilateral optic nerve compression by ICA</th>
</tr>
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<tbody>
<tr>
<td><strong>Number of patients</strong></td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>Controls</td>
</tr>
<tr>
<td>NTG</td>
</tr>
</tbody>
</table>

NTG, normal tension glaucoma.
Optic nerve compression by carotid artery in NTG

Table 3  Optic disc cupping and the frequency of optic nerve compression in NTG

<table>
<thead>
<tr>
<th></th>
<th>Number of eyes</th>
<th>No compression (%)</th>
<th>Compression (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyes with a C/D ratio ≥0.7</td>
<td>95</td>
<td>45 (47.4%)</td>
<td>50 (52.6%)</td>
</tr>
<tr>
<td>Eyes with C/D ratio &lt;0.7</td>
<td>8</td>
<td>7 (87.5%)</td>
<td>1 (12.5%)</td>
</tr>
</tbody>
</table>

C/D ratio, cup/disc ratio; NTG, normal tension glaucoma.

Optic nerve compression was detected in only 21.2% of the control group. This difference was also statistically significant.

Earlier, Umihara et al studied 16 patients with NTG and 16 patients with high tension glaucoma. They reported that compression of the optic nerve by the ICA was found in 24 (75%) of 32 optic nerves and bilateral compression was observed in 12 NTG patients. In the patients with high tension glaucoma, compression of the optic nerve by the ICA was found in 12 (37.5%) of 32 optic nerves and bilateral compression occurred in only three patients. Our findings are comparable to these values, and the values support our hypothesis that optic nerve compression by the ICA can be a possible cause of NTG in some patients.

Additional support of our hypothesis was the finding of a higher percentage (52.6%) of optic nerve compression in NTG eyes with C/D ratio ≥0.7 than in eyes with C/D ratio <0.7 (12.5%). The difference was statistically significant and indicated that optic nerve compression by ICA may contribute the optic disc damage or at least may be a risk factor. It is widely accepted that the C/D ratio is correlated with the severity of visual field defects, and alterations of the C/D ratio can be detected by biomicroscopy. The C/D ratio is not affected by the condition of the patients, such as those with cataracts. However, a previous report could not find significant differences in visual field variables in NTG patients with or without compression, therefore additional studies are necessary to determine the relation between optic nerve compression and severity of visual field defects.

It should be emphasised that our data do not directly indicate that neurosurgical procedures to decompress the optic nerve by ICA should be performed in all patients with NTG, because almost a half of NTG patients (50.5%) did not have a compression of the optic nerve, and control patients with compression of optic nerve are asymptomatic. Thus, additional studies with long term follow up will be necessary to determine how optic nerve compression is contributing to the optic neuropathy in NTG and in the prognosis of NTG, because an aetiologial association is still unknown.

Table 4  Frequency of the compression of optic nerve by ICA in patients with DM and HT

<table>
<thead>
<tr>
<th></th>
<th>Number of patients</th>
<th>Number of eyes</th>
<th>Number of eyes without compression (%)</th>
<th>Number of eyes with compression (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>52</td>
<td>104</td>
<td>68 (65.4)</td>
<td>36 (34.6)</td>
</tr>
<tr>
<td>Without diabetes</td>
<td>35</td>
<td>70</td>
<td>45 (64.3)</td>
<td>25 (35.7)</td>
</tr>
<tr>
<td>With diabetes</td>
<td>17</td>
<td>34 (32.7%)</td>
<td>23 (67.6)</td>
<td>11 (32.4)</td>
</tr>
<tr>
<td>Without HT</td>
<td>22</td>
<td>44</td>
<td>30 (68.2)</td>
<td>14 (31.8)</td>
</tr>
<tr>
<td>With HT</td>
<td>30</td>
<td>60 (57.7%)</td>
<td>38 (63.3)</td>
<td>22 (36.7)</td>
</tr>
<tr>
<td>NTG</td>
<td>54</td>
<td>103</td>
<td>52 (50.5)</td>
<td>51 (49.5)</td>
</tr>
<tr>
<td>Without diabetes</td>
<td>47</td>
<td>89</td>
<td>42 (47.2)</td>
<td>47 (52.8)</td>
</tr>
<tr>
<td>With diabetes</td>
<td>17</td>
<td>34 (13.6%)</td>
<td>10 (71.2)</td>
<td>4 (28.9)</td>
</tr>
<tr>
<td>Without HT</td>
<td>37</td>
<td>71</td>
<td>35 (49.3)</td>
<td>36 (50.7)</td>
</tr>
<tr>
<td>With HT</td>
<td>17</td>
<td>32 (31.5%)</td>
<td>17 (53.1)</td>
<td>15 (46.9)</td>
</tr>
</tbody>
</table>

DM, diabetes mellitus; NTG, normal tension glaucoma; HT, hypertension.
Characteristics in some of the reported patients.39 23 25 12–34

Patients with compressive optic neuropathy show loss of central acuity associated with relative central and cecocentral scotomas. While it is possible and common for these patients to present with additional arcuate visual field defects, and some patients have nerve fibre bundle visual field defects minimising the potential for diagnostic confusion between the two disorders, most patients have additional signs atypical for glaucoma, including a decrease of visual acuity, abnormal colour vision, a central scotoma, and pallor of the neuroretinal rim, and the finding of increased cupping is unusual.

Systemic hypertension and diabetes are major causes of vascular dysfunction.36–39 However, the presence of diabetes or hypertension in patients with NTG did not alter the percentage of cases with compression of the optic nerve by the ICA. In the control group, the percentage of cases with systemic hypertension and diabetes was relatively higher because the patients had been treated at the Department of Internal Medicine. Although this may have biased the findings in the controls, this did not affect the percentages of optic nerve compression by the ICA.

Although neuroimaging studies have been recommended to be performed in the diagnostic evaluation of patients with NTG,29 most patients with NTG do not routinely undergo neuroimaging, and only those who are judged to be atypical (for example, poor correlation between the pattern or amount of visual field loss and optic disc cupping) or are at a high risk of having an intracranial mass are examined. In this study, none of the patients diagnosed with NTG had neuroradiological evidence of an intracranial mass lesion involving the anterior visual pathways, even though there have been several reports of the high prevalence of intracranial mass lesions in patients with NTG.35 37 39 More recently, it was reported that 6.5% patients with NTG have clinically relevant intracranial compressive lesions involving the anterior visual pathway.40 While some have advocated obtaining neuroimaging in patients with NTG,26 40 Greenfield et al suggested that routine neuroimaging may be of little value because of its low sensitivity for detecting such lesions.37 The high spatial resolution and multiplanar imaging capability of CT scan, and the more recent MRI techniques, provide the clinician with non-invasive ways to evaluate the intracranial mass and the relation between the ICA and optic nerve. Although the cost-benefit ratio of performing such studies is still unknown, but weighing the financial implications against the improved quality of life, neuroimaging of NTG patients should be considered.

In conclusion, our study demonstrated that the frequency of compression of the optic nerve by ICA and also bilateral optic nerve compression in eyes with NTG was significantly higher than in the control group. These differences suggest that optic nerve compression by ICA may be one of the possible causes or may be a risk factor for optic nerve damage of NTG in some patients.

Acknowledgements

This study was supported in part by a grant in aid for scientific research from the Ministry of Education in Japan and by the Japan Association for Inhibition of Blindness.

Authors’ affiliations

N Ogata, M Imaizumi, M Auchi, M Matsunura, Department of Ophthalmology, Kansai Medical University, Moriguchi, Osaka, Japan; H Kukawas, Department of Radiology, Osaka Saiseikai Izu Hospital, and Department of Radiology, Kansai Medical University, Moriguchi, Osaka, Japan.

*These authors contributed equally to this manuscript.

References


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- Dr Iona Heath, Chair BMJ Ethics Committee—research, audit, and ethics committee approval
- COPE’s new website—full text and keyword searching for COPE’s advice on specific issues, for example research misconduct, conflict of interest, and deception
- Interactive workshops—common ethical and editorial dilemmas for editors
- Opportunities to network with other editors and share your experiences and challenges

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