THE NEW PREOPERATIVE TEST OF COLLATERAL CEREBRAL CIRCULATION

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INTRODUCTION

The surgical treatment of intracranial aneurysms has been advanced in the past twenty years by several distinguished studies. The proof that elective ligation of carotid artery in the neck is relatively safe in cases of intracranial aneurysms, has been done by the collective work of British neurosurgeons and by the work of Matas and Dandy. In 1934, Matas described about preoperative tests of the efficacy of the collateral circulation by compression of a carotid through the intact skin (Matas test). But, there is no objective proof in the test of percutaneous compression of the carotid.

The corneal pulse wave is a kind of wave motion transmitted directly from the pulsation of the intraocular artery, and is significant for the diagnosis in intracranial circulatory system.

The purpose of this study is to examine the value of the corneal pulse wave as an objective means of determining the efficacy of the collateral circulation by digital compression.

MATERIALS AND METHODS

Apparatus for experiment.

Recently, Prof. Uemura and Dr. Kawashima of our clinic devised an instrument called Keio University's Electronic Retinal Artery Sphygmotonometer which registers the corneal pulse wave and at the same time measures the blood pressure of the central retinal artery. They introduced an improved apparatus in another paper.

Experiment were performed on 2 cases of intracranial aneurysms. Prior to any surgical intervention the competence of the uninvolved cerebral circulation should be evaluated in order to be assured that cerebral ischemia will not be produced by interrupting the blood flow to the aneurysm.
Matas recommended a preoperative test of the efficacy of the collateral circulation by percutaneous carotid compression. He said that this test had four purposes as follows:

(1) A preliminary test of collateral circulation.
(2) A means of developing collaterals when demonstrated incompetent.
(3) A therapeutic agent when compression is well tolerated and can be continued systematically for relatively long period: and
(4) A test of hyperexcitability of the carotid sinus and its cardiovascular reflexes.

Corneal pulse waves of both eyes were recorded before and during the carotid compression every five to ten minutes. The author made analysis of the wave forms and both results were compared.

RESULTS

Case 1.: 26-year-old woman. She was admitted with protrusion and congestion of the right eye on February, 1956.

Physical examination was essentially negative except that the right eye was moderately proptosed, tense, and congested, with lateral displacement.

Hertel exophthalmometer reading were: O.D., 16mm, O.S., 12mm. Vision was: O.D., 20/20, O.S., 20/20, Tension was: O.D., 27mmHg O.S., 19mmHg (Schiotz).

There was marked injection of the sclera and conjunctiva. Funduscopic examination, O. D., revealed a normal disc, slightly dilated veins, but no hemorrhages or exudates. An audible bruit with systolic accentuation was detected over the right globe and the right side of the forehead. Manual compression of right carotid diminished this phenomenon. The presence of a communicating aneurysm between the right internal carotid artery and the cavernous sinus was demonstrated by cerebral arteriography.

A diagnosis of carotid cavernous fistula was made. Permanent arrest of such a condition can only be expected when the fistulous circuit has been surgically interrupted. Prior to surgical intervention, Matas Test was performed in order to know the efficacy of the collateral circulation. As this patient complained the insensibility of left arm and dizziness after seven minutes compression of right carotid, the test had to be stopped. Accordingly, the test was positive.

The corneal pulse waves which were recorded in Mates Test is shown as Fig. 1.

Fig. 1 (a), shows corneal pulse waves before the carotid compression, it is no difference between right and left eye.

Fig. 1 (b), shows the corneal pulse waves immediately after right carotid
compression. The figures show disappearance of pulse wave forms (right eye), but it was found that there was no changes in the pulse waves of the left eye.

Fig. 1 (c), shows the corneal pulse waves after five minutes compression of right carotid. The right corneal pulse wave reappeared after five minutes but, the reduction of wave height and area showed clearly. There was no changes in the pulse wave of left eye as well.

The main results are summarized in Table 1. From Table 1, it is evident

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<td>Max.</td>
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<tr>
<td>Before right Carotid Compression</td>
<td>R</td>
<td>70</td>
<td>50</td>
<td>56.7</td>
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<tr>
<td></td>
<td>L</td>
<td>66</td>
<td>34</td>
<td>44.7</td>
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<td>After 5 minutes Compression</td>
<td>R</td>
<td>54</td>
<td>42</td>
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<td>L</td>
<td>68</td>
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the compression of right common carotid produced a reduction in systolic central retinal arterial pressure (RAP) to 23%, diastolic pressure to 16%, and mean pressure to 19% of the original values prior to carotid compression. Minute area decreased to 31% of the original values. On the other hand, it was found that there was no changes in the corneal pulse waves, RAP and minute area of the left eye by right carotid compression. These results indicate clearly that this patient has a circle of Willis to carry blood to supply both cerebral hemispheres when right carotid artery is obstructed, but the efficacy of the collateral circulation is insufficient.

**Progressive carotid compression**

It must be realized that progressive carotid compression will not allow a patient with a defective circle of Willis to develop tolerance for carotid ligation. It is only in the cases with vessels capable of developing sufficient collaterals that the procedure is of value. The foregoing results indicate that this patient has the collateral circulation, but the efficacy is insufficient. Digital compression of the right common carotid was carried out several times daily with increasing frequency and for progressively longer periods ranging from 1 to 45 minutes. After 25 days the carotid compression was well tolerated and could be continued 45 minutes. During this procedure, the corneal pulse wave were taken and their results were

![Fig. 2](image-url)
PREOPERATIVE TEST OF COLLATERAL CEREBRAL CIRCULATION

compared by forgoing method. The main results are summarized in Fig. 2 and Fig. 3.

Five days later, the carotid compression could be continued 18 minutes. The

right RAP showed a reduction in systolic pressure to 10% of the original values, but there was no noticeable fall in diastolic pressure after 10 or 15 minutes compression of right carotid. On the other hand, the left RAP revealed increases of systolic pressure to 15% of original values after 10 minutes compression and, to 31%, after 15 minutes compensatory. Diastolic pressure; mean pressure and minute area of the left corneal pulse wave as systolic pressure showed definite increases.

Twenty five days later, it is evident that progressive carotid compression (right side) produced a reduction in right systolic pressure to $-14$, $-10$, $-10\%$ of the original value after 15, 30, 45 minutes, and in diastolic pressure to $-28$, $-14$, $+14\%$ after 15, 30, 45 minutes compression. Mean pressure changed to $-23$, $-12$, $+4\%$ of the original values after 15, 30, 45 minutes.

On the other hand, compared these results I found that left RAP showed increase of systolic pressure to $+20$, $+58$, $+20\%$, diastolic pressure to $+32$, $+33$, $+2\%$ and mean pressure to $+25$, $+44$, $+11\%$ of original values after 15, 30, 45 minutes compression. Minute area showed marked increase as well as RAP compensatory.
These results may indicate that the study of the corneal pulse wave changes during progressive carotid compression will clear up the process of development of intracranial collateral circulation.

Case 2: 37-year-old woman. She was admitted with double vision and ptosis of the right eye on March, 1957.

Physical examination was essentially negative except paralysis of ocular motor nerves of the right eye. Herter exophthalmometer readings were: O. D., 13 mm, O.S., 13 mm, Vision was: O.D., 20/20, O.S., 20/20. The relative large aneurysma of the intracranial portion of the right internal carotid artery was demonstrated by cerebral arteriography. Diagnosis of intracranial aneurysma was made.

Matas test was performed in order to know the efficacy of the collateral circulation like in case 1. The recorded pulse waves in Matas test show as in Fig. 4.

In this case no corneal pulse wave form was found at any time over periods up to 20 minutes of continuous compression of the right carotid (Fig. 4).

![Fig. 4 Corneal pulse wave of the right eye (the 1st day)](https://example.com/fig4.png)

After 20 minutes compression the corneal pulse wave reappeared gradually, but the wave showed a reduction of height and area clearly. On the other hand, it was found that there was no changes in the corneal pulse waves of the left eye. These results indicated that the case had a circle of Willis, but the efficacy of the
collateral circulation was insufficient. Then, this patient was given the progressive carotid compression daily with increasing frequency and for progressively longer periods.

Twenty days later, the carotid compression could be continued 40 minutes. The right corneal pulse wave disappeared immediately after compression to 20 minutes later as well as in the first day. On the other hand, there was no change in the corneal pulse wave of the left eye. This results indicate that the development of the collateral circulation is still more insufficient, so that it is danger to perform the ligation of the right internal carotid under such a condition. Also foregoing results suggest for us to be necessary to continue the exercise of the carotid compression. The pulse waves that were recorded after 35 days are indicated in Fig. 5. In this time the compression was well tolerated and could be continued 60 minutes. The right corneal pulse wave appeared already immediately after compression of the right carotid, but the waves showed the reduction of height and area clearly. But, there was no remarkable difference in the pulse wave between before and after 10 minutes compression of the right carotid (Fig. 5). On the other hand, the left corneal pulse wave showed clearly the increase of wave height and area compensatory, especially after 30 minutes compression of left carotid. The author confirmed that such a change of corneal pulse wave in the progressive carotid compression gave us evidence of increased collateral supply. From this result and the absence of cerebral excitement or other untoward symptoms, it may be assumed that the contralateral carotid and the vertebral arteries will provide adequate cerebral circulation.

Surgical treatment
The ligation of the right internal carotid artery was performed under local anesthesia for both cases.

Case 1. The audible bruit and the subjective head noise were no longer present postoperatively and the proptosis was diminished. But, by the second postoperative days hemiplegic signs produced. Anticoagulant therapy and blocking of ganglion stellate were initiated. Thus, one month later, hemiplegic signs disappeared completely. The patient was symptom-free and continued to show daily recession of proptosis and congestion of the conjunctiva. There was good motility of the globe except in lateral direction.

Case 2. The patient was symptom-free following surgery and continued to show daily recession of the paralysis of oculomotor nerve. But I could not found the hemiplegic sign or other neurological deficit in this case postoperatively.
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Fig. 5 Corneal pulse wave (35 days later).

Right eye
a: Before compression
b: Immediately after compression
c: After 10 minutes compression
d: After 30 minutes compression
e: After 50 minutes compression

Left eye
a': Before compression
b': After 5 minutes compression
c': After 10 minutes compression
d': After 30 minutes compression
e': After 50 minutes compression
Consideration for corneal pulse waves before and after ligation of the internal carotid artery.

The change of the corneal pulse waves due to ligation of the one side (right side) of the internal carotid artery.

The recorded corneal pulse wave one month after operation is shown in Fig. 6. The slight reduction of wave height and area shows, but the wave form is not changed. The change of RAP and minute area are summarized in Table 2. These results are similar to the results of after 25 days compression as described.

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<tr>
<td>Before ligation of right internal carotid</td>
<td>R</td>
<td>70</td>
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<tr>
<td>After 1 month ligation of right internal carotid</td>
<td>R</td>
<td>61</td>
<td>51</td>
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<tr>
<td></td>
<td>L</td>
<td>72</td>
<td>38</td>
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<tr>
<td>After 3 month ligation of right internal carotid</td>
<td>R</td>
<td>60</td>
<td>40</td>
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<td></td>
<td>L</td>
<td>62</td>
<td>37</td>
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in the foregoing, but only the minute area of the former is more larger than of
the later. The corneal pulse wave three month after operation is shown in Fig.
6. The author could not find the difference in the pulse wave between right eye
(ligation side) and left eye.

DISCUSSION

The value of the Matas Test which is a preoperative test of the efficacy of
the collateral circulation by percutaneous carotid compression has been discussed by
many neurosurgeons.

Jefferson has noted in his clinical material that the test of percutaneous
compression of the carotid might be negative and yet tying of the carotid produced
hemiplegic signs. He suggested intracranial vascular spasm following the ligation
as the cause of the discrepancy. Sweet and Bennett concluded that preoperative
tests of the efficacy of the collateral circulation by compression of a carotid
through the intact skin were unreliable, and that test should be made wherever
possible by direct positive occlusion of the vessels in an open wound under local
anesthesia where closure was contemplated. Hamby stated that the value of the
Matas test depend on securing full compression by the percutaneous route, so that
when this test performed, the assistant had to be confirmed the security of the
compression by palpation of the superficial temporal artery.

The author call attention particularly to the disappearance or the reduction of
wave height and area of the corneal pulse wave after carotid compression. These
facts and marked fall of RAP are interpreted by us as evidence that occlusion of that
vessel may indeed be effective therapeutically in reducing the hydrostatic pressure
and pulse pressure in intracranial arteries. Such a fall would not only relieve the
aneurysmal wall of rhythmic expansive forces which is not stressed to bear, but
may also be a major factor in permitting a healing clot to develop in the aneurysm.
One may inquire how long-lasting are the pressure falls produced by the carotid
compression. The fact that Sweet and Bennet found no difference in the internal
carotid artery at the beginning and again at the end of the half hour period of
occlusion, is indicating that the extensive pressure drop was maintained during at
least that brief time. On the other hand, my experiments point out that the initial
drop of the RAP slightly recovered by and by with prolonged compression. I
suppose that such a difference probably due to the difference of the portion of
vessels where measurements were taken. The measurements reported this paper were
performed in the RAP. Retinal artery was in distal portion of the internal carotid
artery compared with the internal carotid artery of the neck where measurements
were taken by Sweet and Bennet. Therefore, the former vessel was liable to be
influenced by collateral supply compared with the latter vessel.

Sweet revealed that occlusion of the internal jugular vein following occlusion of the internal carotid artery caused during 30 minutes, no rise in pressure within the artery in cases without a carotid-cavernous fistula. But, Adson suggested that ligation of the internal jugular vein might have greater likelihood of exertion some measurable delaying action in the venous return in the cases of carotid-cavernous fistula.

In this study this author found increasing of diastolic RAP with prolonged compression (Case 1). It has been contended that if a common carotid artery was occluded, collateral circulation would be supplied to the brain by a flow of blood into the corresponding internal carotid from the external carotid on the same side, i.e. the latter vessel receiving its blood from anastomosis with branches of the other external carotid. Dorrance cited 20 authors who argued that there might be significant retrograde flow from the external carotid into the internal carotid after occlusion of the common carotid.

The author did not find adequate data from these experiments to give a solution of these problems. The data the author has acquired appear to us to be of sufficient value to suggest frequent clinical application, and he is trying to set up a method for regular use.

SUMMARY AND CONCLUSION

The author examined the change of the corneal pulse waves on the preoperative test of the efficacy of the intracranial collateral circulation by percutaneous carotid compression (Matas Test) and on the progressive carotid compression, and compared the condition of corneal pulse waves a month later and 3 months later from the ligation of the internal carotid with the preoperative condition of the waves. The experiments allowed us to get a knowledge of the collateral circulation of ophthalmic arteries and of the course of its faculty development, and to conjecture the fall of the pressure on aneurysm in peripheral carotid arteries and the standstill or the slowness of blood stream. It is presumable that this experiment has objectivity in Matas Test as the preoperative test of the carotid ligation, as well as cerebral arteriography.

REFERENCES
