Direction of Blood Flow in the Internal and External Carotid Arteries Following Occlusion of the Ipsilateral Common Carotid Artery

Observation in 19 Patients*

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Recent studies by Hardesty et al. using an electromagnetic flowmeter have shown that in a number of patients there is a reversal of the direction of blood flow in the internal carotid artery following complete occlusion of the ipsilateral common carotid artery. This finding, first predicted by Sweet and associates on the basis of differentials in intravascular pressure in the internal and external carotid arteries following proximal occlusion, refutes the contention that the flow of blood is from external to internal carotid following occlusion of the ipsilateral common carotid artery. However, there have been no studies in which the actual measurement of flow in the external-internal carotid system was correlated with reduction of pressure in these two vessels following proximal occlusion.

The present study was undertaken in an effort to determine the relationship between intravascular pressure and the direction of flow in the internal carotid following complete occlusion of the common carotid artery. In addition, an attempt was made to correlate the direction of flow with the degree of cross-filling of the intracranial circulation as determined by carotid arteriography during compression of the contralateral carotid artery.

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Method and Case Material

Studies were done in 19 male patients undergoing surgery on the carotid vessels in the neck. Their ages ranged from 27 to 73 years. The diagnoses in this group of patients are shown in Table 1. In 5 patients with congenital intracranial aneurysm, surgery was carried out to accomplish a gradual ligation of the common carotid artery by means of a Crutcher clamp. In 8 patients with a diagnosis of tumor, surgery was done to insert a polyethylene catheter in the superior thyroid artery for infusion of an antitumor agent. In the 2 patients with extracranial carcinoma, the tip of the catheter was threaded into the external carotid to prevent spilling over into the internal carotid artery. In the 6 patients with brain tumor, the catheter was inserted into the superior thyroid artery and the external carotid artery above this branch was ligated. Exposure of the vessels in the neck in the patient with communicating hydrocephalus was done to complete the procedure of ventriculo-auriculostomy, a catheter being inserted into the common facial vein, threaded down the internal jugular vein and into the right auricle. An endarterectomy was performed in each of the 4 patients with symptomatic arteriosclerotic stenosis of the internal carotid artery in the neck. Studies of blood flow and pressure were performed before these surgical procedures were carried

† In each patient, craniotomy and subtotal resection of the tumor had been performed. The type of tumor in each case was glioblastoma multiforme.
**TABLE 1**

Mean intravascular pressure and determination of blood flow in the carotid vessels during free flow and proximal occlusion

<table>
<thead>
<tr>
<th>Case</th>
<th>Age</th>
<th>Diagnosis</th>
<th>Reduction in Mean Pressure after Proximal Occlusion (Per cent)</th>
<th>Flow in External Carotid after Common Carotid Occlusion</th>
<th>Cross-Filling on Arteriogram</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Internal Carotid</td>
<td>External Carotid</td>
<td>Common Carotid</td>
</tr>
<tr>
<td>1</td>
<td>28</td>
<td>Comm. hydrocephalus</td>
<td>57</td>
<td>36</td>
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<tr>
<td>2</td>
<td>42</td>
<td>Aneurysm ant. comm.</td>
<td>56</td>
<td>42</td>
<td>49</td>
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<tr>
<td>3</td>
<td>73</td>
<td>Brain tumor</td>
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<td>51</td>
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<td>4</td>
<td>66</td>
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<td>*83</td>
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<tr>
<td>5</td>
<td>71</td>
<td>Carotid stenosis</td>
<td>79</td>
<td>48</td>
<td>67</td>
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<tr>
<td>6</td>
<td>47</td>
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<td>55</td>
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<td>47</td>
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<tr>
<td>7</td>
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<td>Brain tumor</td>
<td>69</td>
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<td>66</td>
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<tr>
<td>8</td>
<td>35</td>
<td>Carotid-cavernous fistula</td>
<td>R. 40</td>
<td>17</td>
<td>34</td>
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<td>L. 69</td>
<td>19</td>
<td>64</td>
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<tr>
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<td>47</td>
<td>Carcinoma nasopharynx</td>
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<td>33</td>
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<td>68</td>
<td>Brain tumor</td>
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<td>10</td>
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<tr>
<td>12</td>
<td>54</td>
<td>Carotid stenosis</td>
<td>38</td>
<td>58</td>
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<td>Carotid stenosis</td>
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<td>38</td>
<td>Aneurysm mid-cerebral</td>
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<tr>
<td>17</td>
<td>37</td>
<td>Aneurysm mid-cerebral</td>
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<tr>
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<td>48</td>
<td>Aneurysm int. carotid</td>
<td>60</td>
<td>60</td>
<td>57</td>
</tr>
</tbody>
</table>

* Before endarterectomy
† After endarterectomy
Direction of Blood Flow after Carotid Occlusion

out in all cases and following the endarterectomy in 2 cases. Surgery was performed in the patient with a post-traumatic carotid-cavernous fistula on the left side in order to ligate the cervical portion of the internal carotid artery on the side of the fistula. Studies of flow and pressure were done on both sides at this time. A craniotomy was performed following completion of these studies and the left internal carotid artery was occluded with a tantalum clip above the cavernous sinus, thus completing a "trap ligation" of the internal carotid artery.

Quantitative determinations of blood flow were obtained using a square-wave electromagnetic flowmeter. **Calibration of this instrument had been carried out by passing known increments of blood through the sensing probes in a given period of time. Flow was measured from the intact, exposed external carotid artery. The size of probe was chosen so that the vessel was constricted only enough to obtain an adequate signal. Zero flow was obtained by temporarily occluding the vessel just distal to the probe. Both mean and pulsatile flows were recorded in each patient. All recording was carried out on a Honeywell Model No. 906 Visicorder.

After obtaining baseline measurement of flow in the external carotid artery for a period of 2 to 3 min., the common carotid artery was completely occluded temporarily, and the volume and direction of flow in the external carotid were measured. A deflection of the recording galvanometer above the baseline, or zero flow, when the flow is in one direction changes to a deflection below baseline following a change in the direction of flow. Thus, the electromagnetic flowmeter in addition to providing quantitative data on the blood flow, will also indicate a change in the direction of flow. This procedure of occluding the common carotid artery and observing the direction of flow in the external carotid artery was repeated at least once in each patient.

Measurements of intravascular pressure were obtained in all patients with a Statham Model P23AA transducer through an 18-gauge needle and flexible but nondistensible connecting tubing. Systolic and diastolic pressures were recorded directly and mean pressure was calculated by adding one-third of the pulse pressure to the diastolic pressure.

In 7 patients the needle was inserted into the external carotid artery following completion of the studies of flow and the resting pressure was recorded continuously for 2 to 3 min. Proximal occlusion of the external carotid artery was performed with smooth forceps and the resulting reduction in pressure was measured. The needle then was inserted into the internal carotid artery and the pressure during free flow and proximal occlusion of this vessel was observed. Since the control pressure varied only slightly, the percentile reduction in intravascular pressure in both the internal and external carotid arteries following proximal occlusion of each vessel could be compared. The control pressure and pressure following occlusion of the common carotid artery also were determined.

In the remaining 12 patients, the needle was inserted into the common carotid artery immediately below its bifurcation. After a control pressure was obtained, the common carotid artery proximal to the recording needle was occluded completely. The resultant reduction in pressure was recorded continuously and, when it became stable, the internal and external carotid arteries were occluded alternately, the latter vessels each being occluded for a period of time to allow the resultant changes in pressure to stabilize. After completing these measurements, which usually required about 30 min., the intended surgical procedure was then accomplished.

Carotid arteriography with compression of the contralateral carotid was performed in 9 of the 19 cases prior to the measurements of flow and pressure in the carotid vessels. This procedure was done in an effort to correlate the direction of flow in the external carotid artery after occlusion of the ipsilateral common carotid with the adequacy of the intracranial collateral circulation through the circle of Willis. The arteriogram was carried

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out on the side opposite to that on which the measurements of flow and pressure were to be made. Anteroposterior roentgenograms of the skull were made during two separate injections of 10 cc. of 50 per cent Hypaque (sodium diatrizoate), one injection being made with and the other injection without compression of the contralateral carotid artery. In this manner, the presence or absence of cross-filling could be determined and correlated with the change in circulatory dynamics in the external and internal carotid arteries during temporary occlusion of the ipsilateral common carotid artery.

Results

A. Direction and Volume of Flow. The results of this study are shown in Table 1. There was a reversal of flow in the external carotid artery in 8 of 19 patients during complete occlusion of the ipsilateral common carotid artery. This reversal of flow ranged from 20 cc./min. to 180 cc./min. In the patient (Case 8) with the carotid-cavernous fistula, measurements were made on both sides. Reversal of flow occurred in both external carotid arteries following occlusion of the respective common carotid artery. On the side of the fistula, the reversed flow was 180 cc./min. and on the opposite side it was 95 cc./min.

The flow of blood continued in a forward direction in the external carotid following temporary occlusion of the common carotid artery in 10 patients. This finding must result from reversed flow in the internal carotid artery. The reversed flow ranged in value from 12 cc./min. to 90 cc./min. In Case 19 repeated measurements were made with the probe alternately on the internal and external carotid arteries during temporary occlusion of the carotid. Although 5 to 7 cc./min. of flow of blood was observed occasionally in each of these vessels, there was usually no flow in either the internal or external carotid artery during occlusion of the ipsilateral common carotid.

In every case, the direction of flow in the external carotid artery following occlusion of the common carotid corresponded to the reductions in pressure in the internal and external carotid arteries following proximal occlusion of these vessels, i.e. flow was in the direction of the greater reduction of pressure. In each of the 8 cases showing reversal of flow in the external carotid artery (Cases 1–8) the percentile reduction in pressure in the internal carotid artery was greater than the reduction in the external carotid following proximal occlusion. For example in Case 6 (Fig. 1), the reduction in the internal carotid following proximal occlusion of this vessel was 55 per cent, whereas reduction in the external carotid artery was 38 per cent. In this case, blood flowed from external to internal during occlusion of the common carotid artery. Reversal of flow in the internal carotid artery occurred in the 10 patients (Cases 9–18) in whom the percentile reduction in the external carotid exceeded that in the internal carotid artery. As an example (Figs. 2 and 3), the reduction in the external and internal carotid arteries was 41 per cent and 24 per cent, respectively, and the direction of flow was from internal to external carotid artery. The reductions in pressure in the internal and external carotid arteries in Case 19 were identical; thus the finding of zero blood flow in these vessels during most of the period of observation.

The direction of flow following occlusion

![Fig. 1. Case 6. Reverse flow in external carotid artery. A forward flow of 64 cc./min. in external carotid changes to reverse flow of 32 cc./min. following complete occlusion of common carotid artery. A deflection of the recording below baseline indicates a change in direction of flow. The reduction in pressure in internal and external carotid arteries (not shown in this figure) was 55 per cent and 38 per cent respectively. The lag in the tracing of the mean flow is related to the electronics of the recording system. The gain for the mean channel is five times that for the pulsatile channel, and the scale in cc./min. refers to mean flow.](image-url)
of the common carotid bore no consistent relationship to the actual flow in the unobstructed external carotid artery. In general, the percentage of reduction in intravascular pressure in the common carotid artery following proximal occlusion correlated with the direction of flow in the internal-external carotid system, in that patients with a considerable reduction in pressure showed reversed flow in the external and those with minimal or moderate reduction in pressure showed reversed flow in the internal carotid artery.

B. Arteriographic Correlation. Carotid arteriography with compression of the contralateral carotid artery was performed in 9 patients to determine the adequacy of the intracranial collateral circulation. The procedure was satisfactory technically in all except Case 13. There was a good correlation between the direction of flow in the external carotid artery and the presence or absence of cross-filling on the anteroposterior arteriogram. In 5 patients (Cases 9, 10, 11, 12 and 14) who showed ample cross-filling (Fig. 4), the direction of flow was reversed in the internal carotid following occlusion of the common carotid artery. In each of the 5 cases both anterior cerebral and both middle cerebral arteries filled from the side of injection during compression of the contralateral carotid artery. On the other hand, in 2 patients (Cases 2 and 3) in whom there was poor cross-filling (Fig. 5), the direction of flow was reversed in the external carotid following occlusion of the ipsilateral common carotid artery. A brief synopsis of 2 of these cases will make this point clear:

![Diagram](image-url)

**Fig. 2. Case 10.** Reductions in pressure in internal and external carotid arteries. The drop in mean pressure in external carotid of 41 per cent (90 to 53 mm. Hg) exceeds the fall in internal carotid of 24 per cent (88 to 67 mm. Hg). Note that control pressures are similar. The direction of flow following occlusion of ipsilateral common carotid was from internal to external carotid artery as shown in Fig. 3.

![Diagram](image-url)

**FIG. 3. Case 10.** Forward flow in external carotid artery. The rate of flow of 140 cc./min. in external carotid drops to 70 cc./min. during occlusion of ipsilateral common carotid, but continues in the same direction, which indicates a reversal of flow in internal carotid. The vertical lines represent 1-sec. intervals.

The gain setting, lag in tracing of mean flow, and scale of flow are explained in Fig. 1.
**Fig. 4. Case 9.** Right carotid arteriogram without (A) and with (B) percutaneous compression of left common carotid artery. There is ample cross-filling in left anterior and middle cerebral artery as well as into distal portion of left internal carotid artery. Filling of left internal carotid is produced by a reversal of flow in the vessel during occlusion of left common carotid. Craniotomy had been performed in this patient in order to decompress the left optic nerve which was involved with tumor eroding through the base of the skull.

**Fig. 5. Case 2.** Right carotid arteriogram without (A) and with (B) percutaneous compression of left common carotid artery. There is a minimal degree of cross-filling as shown by the fact that only the left anterior cerebral and the aneurysm on the anterior communicating artery are filled.
Case 9. Measurements of flow and pressure were made on the left side. Flow in the external carotid artery was 150 cc./min. Following occlusion of the ipsilateral common carotid artery, flow in the external carotid dropped to 90 cc./min. but continued in the same direction. The only source of this blood was through retrograde flow in the ipsilateral internal carotid artery. A right carotid arteriogram had been performed prior to surgery. There was ample cross-filling (Fig. 4) when the left common carotid was compressed during the injection.

Case 2. A right carotid arteriogram made prior to surgery showed a minimal degree of cross-filling during compression of the left carotid artery (Fig. 5). Measurements of flow and pressure were carried out on the left side. Flow in the external carotid artery was 180 cc./min. Following occlusion of the ipsilateral common carotid artery, there was a reversed flow of 40 cc./min. in the external carotid artery.

In Case 19, the degree of cross-filling was not considered good. A left carotid arteriogram made during percutaneous compression of the right common carotid artery showed the contrast medium to cross into the right anterior cerebral artery only. (Determination of pressure and flow were made on the right side.) The reductions in pressure in the external and internal carotid arteries were such that virtually no flow occurred in either vessel during occlusion of the ipsilateral common carotid artery.

Discussion

The changes in circulatory dynamics above the site of carotid ligation, with particular reference to the direction of blood flow in the internal and external carotid arteries, have interested a number of investigators. Dorrance felt that flow was always from external to internal carotid artery and cited several references in support of this hypothesis. He estimated that ligation of the common carotid reduced the blood flow in the internal carotid artery by about 50 per cent, which if true would represent a considerable retrograde flow in the external carotid artery. However, this estimate was not based on actual measurement of pressure or flow.

Sweet and Bennett in 1948 made observations which suggested that the flow may be reversed in the internal carotid after occlusion of the common carotid artery. Determinations of pressure were made in the exposed internal carotid artery in 8 cases. These workers reasoned that if there is appreciable retrograde flow in the external carotid, then pressure in the internal carotid with the common carotid occluded should be higher with the external carotid open than with it closed. In other words, the direction of flow should be toward the vascular bed with the lower residual pressure following occlusion of the common carotid artery. In 8 cases in which such measurements were made, a small rise in pressure in the internal carotid occurred in 3; in 2 cases no change in pressure was recorded; and in 3 cases a slight fall in pressure was noted. Thus, in these last 3 cases, it was predicted that the direction of flow would be from internal to external during occlusion of the carotid. In a later publication Sweet et al. found in a series of 39 cases the pressure relationships such that in 4 cases the flow was from internal to external and in 2 cases there was significant retrograde flow in the external carotid during occlusion of the common carotid. However, Morfit and Gensini found in a series of 12 patients with presumably normal cerebral circulations that occlusion of the external carotid artery did not affect the mean pressure in the internal carotid when the common carotid artery was occluded. In 1952 Denecke, using a thermal method to measure direction of flow, carried out studies in "over 20 patients" and showed that blood invariably goes from the internal carotid into the external carotid after compression of the common carotid artery.

Hardesty et al. carried out studies on flow in the carotid artery in 15 patients undergoing radical dissection of the neck (usually for carcinoma). Using an electromagnetic flowmeter, they showed that flow was reversed in the internal carotid in 7 of the 15 patients following temporary occlusion of the common carotid artery. In the remaining 8 cases flow continued in a forward direction in the internal carotid artery, prov-
ing that in these cases flow was reversed in the ipsilateral external carotid artery. Retrograde flow in the internal carotid artery in these 7 patients ranged from 18 to 85 cc./min. They did not offer an explanation for this interesting observation other than to state that "... volume and direction of flow through the internal carotid artery immediately after common carotid compression or ligation is highly variable and cannot be predicted." They added further that it would seem that ligation of the common carotid artery in the group in which retrograde flow develops in the internal carotid may actually result in less flow to the brain than ligation of the internal carotid.

The results of the present study are in keeping with the quantitative findings of Hardesty et al. In addition, the study has shown further, as predicted by Sweet et al., that the direction of flow in the internal-external carotid system following occlusion of the ipsilateral common carotid is dependent on the reductions in intravascular pressure in the two vessels following proximal occlusion. Flow is invariably in the direction of the lower residual intravascular pressure (Figs. 2 and 3). The differential of pressure between the two vessels is, in turn, related to the adequacy of the intracranial collateral circulation. In patients with ample cross-filling, it is expected that the drop in pressure in the external carotid system will be greater than that in the internal carotid and the direction of flow will be from internal to external carotid artery. On the other hand, in a situation in which virtually no cross-filling occurs, one would anticipate that the drop in pressure in the internal would be greater than in the external carotid and the direction of the flow would be from external to internal carotid artery.

At first glance, it would seem that ligation of the common carotid artery in a patient in whom the direction of flow in the internal carotid artery is reversed following occlusion of the common carotid would be hazardous, since in this situation the flow of a certain amount of blood would be away from the brain and into the external carotid artery. However, on the basis of the arteriographic findings reported in this study, it is our feeling that this situation is simply an expression of adequate intracranial collateral circulation. The group in which carotid ligation might be potentially hazardous may well be that in which flow is reversed in the external carotid following occlusion of the common carotid artery. However, further study in a larger group of patients will be necessary to determine which situation results in the more deficient cerebral circulation.

The finding of reversal of flow in the internal and external carotid arteries is not peculiar to these vessels. Reivich et al.7 and Mannick et al.9 have demonstrated reversal of flow in the vertebral artery in patients with atherosclerotic occlusion of the ipsilateral subclavian artery. In these cases, the proximal subclavian stenosis produces a drop in distal pressure such that the vertebral artery functions as a source of collateral supply to the arm.

**Summary**

1. In an effort to determine the direction of flow in the internal and external carotid arteries after occlusion of the common carotid artery, determinations of blood flow and intravascular pressure were made in these vessels during temporary occlusion of the ipsilateral common carotid in 19 patients undergoing surgery on the carotid vessels in the neck. Blood flow was determined with an electromagnetic flowmeter.

2. Following occlusion of the common carotid artery, the direction of blood flow reversed in the external carotid in 8 patients, the direction of flow reversed in the internal carotid in 10 patients; and in 1 patient virtually no flow occurred in either vessel.

3. Determinations of intravascular pressure were obtained in both the internal and external carotid arteries during free flow and proximal occlusion. It was found that the direction of flow was dependent on the differential of pressure between the two vessels in that flow was always toward the lower residual intravascular pressure.

4. There was good correlation with the
pattern of cross-filling on the carotid arteriogram and the direction of flow in the internal-external carotid system. In 5 patients in whom there was ample cross-filling, there was reversed flow in the internal carotid artery following occlusion of the ipsilateral common carotid artery, whereas in 2 other patients, who showed deficient cross-filling, there was reversed flow in the external carotid artery.

References


Discussion

Dr. Lester A. Mount: It is a privilege for me to discuss the paper of Drs. Tindall, Odum and their associates, and I wish to congratulate them on it.

This is an important paper. It describes an additional method of evaluating the potential collateral circulation of the brain. A correlation has been made between the direction of blood flow within the external carotid artery after ligation of the common carotid, and the collateral circulation through the anterior part of the circle of Willis as demonstrated arteriographically. I hope that when the authors close the discussion they will give us the correlation of the clinical course of those patients who had carotid ligation. Although this is a small series of cases, still it is significant that there was a reversal of flow within the internal carotid artery. In 1 of these 8 patients, 90 cc. of blood per min. were flowing down the internal carotid artery. In other words, the brain was deprived of 90 cc. of blood per min., more than would have occurred had ligation of the internal carotid been done. In fact, in all 8 of these patients, ligation of the internal carotid should be safer than ligation of the common carotid artery.

Blood flow is in the direction of lesser pressure. After ligation of the common carotid artery, the blood flow within the internal and external carotid arteries is dependent upon balance between the summation of the collateral circulation of the two arteries. The variability in the summation is the result of abnormalities, or other anatomical variations in the two arteries or their branches. Of course, there are other factors, too; such as arteriospasm, or even of turning the head to one side which will reduce the cerebral blood flow half on the opposite side. The collateral circulation of the internal carotid artery can be demonstrated better by arteriography than the external carotid.

The obvious conclusion is that it would be less dangerous to ligate the internal carotid artery than the common carotid artery when the blood flow is down the common carotid after occlusion of the common carotid and less hazardous to ligate the common carotid artery when the blood flow is up the internal carotid after occlusion of the common carotid artery.

Dr. E. S. Gurdjian: Dr. Tindall's paper is very interesting to me personally, since my associates and I have tried to study the direction of blood flow in the internal and external carotid arteries following occlusion of the common carotid artery without the help of the electromagnetic flowmeter, which of course is very much better. In a little more than one-half of our cases, it appeared to us that the flow was from the external carotid into the internal carotid artery. The direction of flow, as the authors have suggested, is a function of the collateral supply of the blood at the base of the brain in the circle of Willis for the internal carotid artery, and, extracranial collateral supply in the case of the external carotid artery.

In the presence of wide-open communications from the one to the other side in the circle, the intraluminal pressure in the internal carotid artery may be much higher and the flow may therefore be from the internal to the external carotid. In other instances, and in actuality in a little over one-half of the cases in our experience, the flow is from the external into the internal carotid because of the more adequate collateral supply to the external carotid artery. One wonders what happens with the passing of time in those instances in which the flow is from the internal into the external. Is there in such cases an increase in the collateral supply to reverse the direction of flow? It would be interesting.
to study this problem in the occasional patient needing re-exploration in which the direction of flow is known by the initial study. In such a case, either by the flowmeter or by recording the level of pressure in the internal and external carotid arteries, one may be able to determine the direction of flow.

(Slide) An increase in the blood pressure in the internal carotid on opening the external carotid, and a decrease in the blood pressure on closing the external carotid are shown in this slide. A vascular clamp has been applied to the common carotid artery. The remaining pressure in the internal drops lower when the external carotid is obliterated. When the external carotid artery is opened, the pressure rises in the internal carotid artery.

This was thought to indicate that the flow was from the external to the internal carotid artery, in this instance.

(Slide) On the other hand, in this instance the opening of the external carotid caused no change in the remaining pressure in the internal carotid. This we thought was an indication that the flow was from the internal into the external carotid artery.

In the cases in which we have ligated the common carotid for intracranial aneurysm of the internal carotid artery, a reversal of flow in the internal carotid did not seem to make any difference in the patient's condition. The prognosis in this group has been no different than among those with flow from the external into the internal carotid.

I enjoyed this paper very much. I would like to ask Dr. Tindall if in cases of patients coming to operation several months after ligation of the common carotid in the neck the findings at the first operation were confirmed at the second study, or if the flow changed during the interim by the development of additional collateral vessels.

Dr. Frank P. Smith: As some of you may know, we have been interested in the technique of so-called differential carotid ligation on which we reported at this meeting last year. I would like to ask Dr. Tindall if by chance he has used the technique of measuring retinal-artery pressure in following some of these patients that have demonstrated the reversal of flow.

We would be concerned about any conclusive clinical ideas on the so-called acute occlusion or acute temporary ligation in contrast to a graded ligation of a carotid artery over a period of 3 or 4 or 5 days. We feel that the technique of differential carotid ligation moderates these changes that have been pointed out by Dr. Tindall.

Dr. George T. Tindall: I wish to thank the discussers for their kind and well-worked out remarks.

In 4 patients with aneurysms, the common carotid artery was gradually occluded with the Crutchfield clamp. In 2 of these patients there was reversal of flow in the internal carotid following temporary occlusion of the common carotid artery; whereas in the other 2 cases, the direction of flow reversed in the external carotid. None of these 4 patients had complications from graded ligation of the common carotid artery. Even though this series is too small to determine any correlation, I would feel that the group in which carotid ligation might be hazardous would be that in which flow in the external carotid reverses following temporary occlusion of the common carotid.

Whether flow in the internal-external carotid system following temporary occlusion of the common carotid continues in the same direction or changes with the passage of time is not known. In none of our patients in whom the common carotid has been gradually ligated has the neck been re-opened at a later time to determine the direction of flow in the internal and external carotid arteries.

In reply to Dr. Smith's question, we have used the technique of determining retinal-artery pressure as a guide in all cases in which we have carried out gradual ligation of the carotid artery. We have these data on 4 patients in this series, but I have not related them to the phenomenon of reversal of flow.