INCIDENCE AND SIGNIFICANCE OF EARLY FILLING OF VEINS IN NORMAL INTERNAL CAROTID ANGIOGRAPHY

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SINCE the discovery of cerebral angiography by Moniz in 1927, this unique method of investigation has been studied extensively and has become an important aid to the neurologist and neurosurgeon in the diagnosis of intracranial lesions. As the literature on the subject became more voluminous, more points of interest and debate began to appear. It is true, as once pointed out by Johanson, that in the angiographic literature, interest has been focussed mainly on the displacement of arteries and the existence of pathological vessels. The appearance of veins was not often taken into consideration. During the last few years, however, there has been increasing interest in the phlebogram and its diagnostic value. Recently Steinhart and his co-workers reported that they could localize brain tumors in 90 per cent of cases from their phlebograms and without previous knowledge of the arteriograms. In 14 per cent of these cases the value of the phlebogram exceeded that of the arteriogram.

One of the most interesting observations that gave added support to the diagnostic value of veins in cerebral angiography was the angiographic demonstration by Tön尼斯 of arteriovenous communications in glioblastomas. The presence of such communications gave rise to the phenomenon of “early appearance of veins” in the angiogram. The significance of this “early” appearance of veins in glioblastomas as well as in other brain tumors was subsequently stressed repeatedly by Tön尼斯 and his assistants as well as by others. Tön尼斯 and Schiefer stated that arteriovenous communications could be observed both radiologically (as “early veins”) as well as at operation (by the presence of red arterial blood in cortical veins) not only in glioblastomas, but also in malignant astrocytomas and oligodendrogliomas, in sarcomas and in metastases. They emphasized the fact that this early appearance of veins in angiograms in all probability denoted the presence of a malignant intracranial tumor.

It is this increasing significance of “early veins” that stimulated the present study. It will be our aim in this paper, the first of a series dealing with “normal and pathological early veins,” to attempt to clarify the concept of “early veins” and to try to find out their possible incidence and significance in the “normal cerebral angiogram.” For a better understanding of the subject under discussion, we found it essential to study first the timing and order of appearance and disappearance of veins in the normal internal carotid angiogram.

“Normal” Material. Two groups of cases were studied: (1) 34 angiograms obtained by rapid serial technique; (2) 220 angiograms obtained by ordinary or routine serial technique (in our material we used the 4-film technique).

It is true that rapid serial angiography would supply the most precise information in the majority of problems under discussion. However, the routine 3- or 4-film method is the more popular technique and is the only one available in most neurosurgical centers; even in the most elaborate centers the rapid serial technique is reserved for special cases

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only. It therefore is our opinion at present, and until the time comes when rapid serial angiography completely replaces ordinary serial angiography, that we should try to obtain the maximal possible information from films taken by the routine technique. In the present study most of the observations and conclusions will be drawn from films taken by the rapid serial technique, but these will be compared with data inferred from routine serial films as much as possible. The potential possibilities of the latter technique should by no means be overshadowed by the more elaborate achievements of modern rapid technique.

"Normal" Cases. Though carotid angiography now is regarded as a safe procedure, it is not yet so absolutely safe as to be attempted experimentally on a normal individual or a "volunteer." All the "normal" cerebral angiograms described in the literature are "normal" only from the point of view of the "angiogram" per se. An individual whose angiogram is stamped as "normal," must have carried such a cerebral ailment as to have necessitated the undertaking of a carotid puncture for angiography.

Schurr and Wickbom defined their "normal angiograms" as those in which no displacement of vessels or other abnormality was visible in any part of the film and when the clinical diagnosis was such that they did not consider it likely that the part of the circulatory system being studied was affected to any significant extent by the disease. Among their "normal" cases were patients with focal epilepsy, otitic hydrocephalus, meningitis, penetrating head injuries, subarachnoid hemorrhage, cerebral arteriosclerosis, thrombosis in the opposite hemisphere, etc.

Greitz patients with "normal" angiograms had headache (12 cases), epilepsy (14 cases), hemangioma of calvarium (1 case), dermoid of facial bone (1 case), arteriovenous malformation of the external carotid (1 case) and single cranial nerve palsies (3 cases).

Concerned as we were with the timing and variations in venous filling, we insisted on avoiding "normal angiograms" of patients harboring a disease that might in any way impede or disturb the venous circulation. Cases of raised intracranial tension (e.g., hydrocephalus, subarachnoid hemorrhage, meningitis, etc.) were excluded; the effect of such a rise of tension in slowing down the cerebral circulation is a common observation in many angiograms. Moreover, acute head injuries with their concomitant edema and venous impediment, as well as post-traumatic conditions with accompanying fibrosis and possible venous obstruction, were rejected. Consequently we were able to limit our cases of routine angiography to patients with epilepsy. Therefore, all the 220 "normal routine serial angiograms" were obtained from patients complaining of idiopathic or focal epilepsy with no demonstrable neurological or angiographic pathology. The group of "normal rapid serial angiograms," on the other hand, included in addition to 17 cases of epilepsy, 5 cases of headache; 7 cases of patients who underwent angiography for suspected vascular processes, but in whom no evidence of vascular pathology was found by angiography; 3 cases of Parkinsonism with no vascular pathology; 1 case of sarcoma of the skull with no intracranial extension; and a case of small hypophysal adenoma with no rise of intracranial tension. Most of these patients had undergone air studies and a good percentage of them were followed-up by control examination and angiography for months or years.

Techniques Used. The techniques of angiography, both routine and rapid methods, were fully described, among others by Tönnis and Schiefer, and will not be given in detail here. However, since we are concerned with the time relationship of the filling of various veins, it is essential to give some information on the intervals of time between the films that we used in both methods:

(a) Routine 4-film technique: In all our 220 cases examined by this technique, the interval of time between each 2 films was fixed automatically at 0.55 of a second (Tönnis-Bergerhoff's 4-4-4 interval type).
EARLY FILLING OF VEINS IN CAROTID ANGIOGRAPHY

(b) Rapid serial technique: In our collection of 34 cases, two combinations of time intervals were used. (i) In 16 cases the first 10 films were taken at a rate of 2 films per sec.; the subsequent films at a rate of 1 per sec. (2-2-1-1 interval type). (ii) In the other 18 cases the rate was 1 film per sec. (1-1-1-1).

This fixation of time intervals allows comparative studies to be achieved, a most important condition for the present study.

I. ORDER OF VENOUS FILLING AND EMPTYING

At first sight it may seem surprising, or rather disappointing, to note the divergent results obtained by different observers on this subject.

Moniz, 13-16 using a 3-film technique with 2-sec. intervals, found the superficial veins to fill in the second film (phlebogram of the first phase) and the deep veins with the dural sinuses to fill in the third film (phlebogram of the second phase). He postulated the presence of a capillary phase between his first (angiogram) and second (phlebogram of the first phase) films, in which no definite vessels could be demonstrated. However, as pointed out by Greitz, 2 this division is not supported by the films published by Moniz himself; so that in most of his illustrations of the phlebogram of the first phase the deep veins were already filled. Moreover, in his illustration intended to demonstrate the capillary phase, 16 contrast filling could be seen in the veins.

It was Wickbom 28 who first pointed out the fact that both the superficial and deep veins often could be demonstrated in the same phlebogram.

Curtis 1 reported his observations on 94 “normal” angiograms (78 done by routine 3-film method and 17 by rapid serial angiography). He found that the deep cerebral veins (almost always the internal cerebral vein), and certain superficial veins along the anterior part of the temporal lobe and the Sylvian point, were the first to be seen. Then the contrast medium appeared in the superficial ascending veins, and the last to be seen were the more posterior veins. He added that the contrast medium, in most cases, disappeared from the deep veins sooner than from the superficial veins and that the last veins to be seen were those situated posteriorly.

Schurr and Wickbom 21 studied 20 rapid serial angiograms. They stressed the frequent occurrence of overlapping of the venous phases. In 15 cases (75 per cent) they were able to confirm the observations of Curtis 1 that the deep cerebral veins and certain superficial veins around the anterior part of the temporal lobe and Sylvian point were the first to be seen. In the remaining 5 cases (25 per cent) the inferior longitudinal sinus was the first vein to be seen. They even added that the inferior sagittal sinus could be seen in some films during the arterial phase. However, in 10 of their cases (50 per cent) this sinus was “not visible at any stage of the angiography.” As regards the sequence of events in the emptying phase, they found both superficial and deep systems emptied simultaneously in 12 cases (60 per cent), the deep first in 3 cases (15 per cent), and the superficial first in 5 cases (35 per cent).

Krayenbühl and Richter 8 found that the outer peripheral ascending and descending veins, and the veins of Trolard and Labbé were the first to fill, and secondly, the big sinuses and internal veins.

Riechert 17 was of the opinion that either the superficial or the deep system may fill first.

Johanson 8,7 and Lindgren 10 found that the inferior sagittal sinus as a rule is one of the earliest veins to fill and that it could be demonstrated in a high percentage of cases towards the end of the arterial phase. The internal cerebral vein, in their view, filled at the same time or a little later than the superficial cerebral veins.

Greitz 2 published his observations on 32 “normal” cerebral angiograms. His technique consisted of taking 2 films per sec. during the first 5 sec. followed by 1 film per sec. for another 10 sec. (20 exposures). He carefully observed the time of filling and emptying not only of the various superficial groups of veins but also of the single deep veins. He tabulated his results on “circulatory diagrams.”
He found that the phase of venous filling as a rule began earlier in the frontal than in the parietal veins, but was sometimes simultaneous. Filling often started earlier in the parietal than in the occipital region, but the latter veins never filled before the former. The middle cerebral vein commenced to fill early, often at the same time as the frontal veins. Among the deep veins, the basal vein and the internal cerebral vein filled approximately together and often at the same time as the parietal ones. The septal vein was conspicuously late in beginning to fill. In his material, the inferior longitudinal sinus was never the first to fill. He suggested that the parietal area may be regarded as a representative area for the average time of filling and emptying of cerebral veins.

Woringer and his co-workers, using a 10-exposure method (the first 5 at 1-sec. intervals and the remaining 5 at 2-sec. intervals), found in their 22 “normal” cases “a simultaneous opacity of one or more veins of both the superficial and deep systems.”

Tönnis and Schiefer found the question of whether the superficial or the deep veins filled first as yet unsettled. They supported the observation of Riechert that both possibilities can take place under normal as well as pathological conditions. As to the sequence of affairs during the emptying phase, they found that both the superficial and deep veins in most cases empty simultaneously; but that in one-third of the cases, the contrast medium remained in the deep veins for a second longer.

Table 1 summarizes the opinions of various authors on this subject.

**Our Observations.** Before recording our results, we shall describe the various groups of veins we studied. Some differences exist in the literature concerning the grouping of the

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**TABLE 1**

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>First Veins to Fill</th>
<th>First Veins to Empty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moniz(^{12-16}) 1922, 1933, 1934, 1940</td>
<td>Superficial</td>
<td>Superficial</td>
</tr>
<tr>
<td>Wickbom(^{28}) 1948</td>
<td>Both groups. Inferior sagittal sinus often fills early</td>
<td>—</td>
</tr>
<tr>
<td>Curtis(^{3}) 1951</td>
<td>Deep &amp; sphenoidal</td>
<td>Deep</td>
</tr>
<tr>
<td>Schurr &amp; Wickbom(^{31}) 1952</td>
<td>75% deep &amp; sphenoidal. 25% inferior sagittal sinus</td>
<td>Both systems simultaneously</td>
</tr>
<tr>
<td>Krayerbühl &amp; Richter(^{4}) 1952</td>
<td>Superficial peripheral</td>
<td>—</td>
</tr>
<tr>
<td>Riechert(^{17}) 1953</td>
<td>Both or any</td>
<td>—</td>
</tr>
<tr>
<td>Johanson(^{6,7}) 1953, 1954</td>
<td>Both systems. Inferior sagittal sinus often first to fill</td>
<td>—</td>
</tr>
<tr>
<td>Lindgren(^{10}) 1954</td>
<td>Both systems together. Inferior sagittal sinus one of first to fill</td>
<td>Simultaneously or deep a little later</td>
</tr>
<tr>
<td>Greitz(^{2}) 1956</td>
<td>Usually frontal first, then parietal, then deep &amp; lastly occipital</td>
<td>—</td>
</tr>
<tr>
<td>Woringer et al.(^{29}) 1958</td>
<td>Both systems</td>
<td>—</td>
</tr>
<tr>
<td>Tönnis &amp; Schiefer(^{27}) 1959</td>
<td>Either system can fill first</td>
<td>Both systems simultaneously. In one-third of cases superficial empty first</td>
</tr>
</tbody>
</table>
superficial veins; but we followed Tönnis and Schiefer’s simple classification of these veins into three groups: the ascending, the sphenoidal and the occipital. A further subdivision of the ascending group into frontal and parietal was found advisable for a better study of the time relationships and to allow for a better comparison of results given by others (e.g. Greitz). However, such a subdivision in its turn was found to introduce a difficulty; namely the further introduction of a third member of this subdivision: the Rolandic vein. Running as it does in the boundary between the frontal and parietal areas and representing one of the distinctive members of the phlebogram, it was found worthy of a special subdivision.

Greitz’s middle cerebral vein of anatomists and Curtis’ “certain superficial veins along the anterior part of the temporal lobe and the Sylvian point” are but synonyms for Tönnis and Schiefer’s sphenoidal group.

As to the internal system of veins, we found it most serviceable, for our purpose, to describe it under the following subdivisions: the inferior sagittal sinus (ISS), the vena septi pellucidi, the basal vein and the deep venous curve. The last name is suggested as representing a collective angiographic morphological term for the thalamostriate vein, the internal cerebral vein and the great cerebral vein. This compound triad was found, in the great majority of cases, to fill up and empty as one unit; thus lending us the authority to consider it, from our point of view, as one block.

**Rapid Serial Group.** Concerned as we are with the early filling of veins, the first vein or group of veins to fill will have a particular place in our statistical study. Table 2 represents the case and percentage frequency of the first veins to fill in our series of 34 “normal” rapid serial angiograms.

<table>
<thead>
<tr>
<th>First Vein or Group of Veins to Fill</th>
<th>No. of Cases</th>
<th>Per Cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>All at the same time</td>
<td>7</td>
<td>20</td>
</tr>
<tr>
<td>Parietal</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>Parietal+rolandic</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>Frontal+rolandic</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Frontal+parietal</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Inferior sagittal sinus+superficial</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Frontal</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Rolandic</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Sphenoidal+frontal+parietal</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Deep venous curve</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Inferior sagittal sinus</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>34</td>
<td>100</td>
</tr>
</tbody>
</table>

It may be inferred from Table 2 that no single vein or subgroup of veins could be described as the first to fill in the majority of cases. However, if we collect the members of the superficial ascending group together (frontal, rolandic and parietal) we find that single representatives or a combination of them showed filling earlier than other groups in 68 per cent of cases. The most evident deduction arrived at, on the other hand, is the fact that the superficial veins filled earlier than the internal veins in 71 per cent of cases, while in the remaining 29 per cent both systems appeared to fill simultaneously. In no case, in the present series, were the internal veins revealed first.

As to the order of filling and emptying of veins, Fig. 1 shows a graphic representation of the relative time and order of appearance and disappearance of the various subgroups in 1 of our cases. However, the case-to-case variations are far more complicated than this simple diagram would suggest. Our observations confirmed to a great extent those of Greitz, with only some minor differences. In contradistinction to Greitz’ findings, we found the parietal veins filled earlier, either separately or in combination with other groups, more commonly than the frontal veins. The frontal and sphenoidal veins often appeared simultaneously, but the occipital veins always appeared at a later stage. The rolandic vein is one of the earliest to fill, usually in combination with one or both of its neighbors, the frontal or parietal subgroups. The deep venous curve often comes into view together with the basal vein just after the appearance of the first superficial subgroups. In a good number of cases the deep veins made their appearance simultaneously with the sphenoidal
veins. The vena septi pellucidi is often the last vein to fill, sometimes after the first superficial veins have already begun to empty. The tributaries of the vena septi pellucidi often could be demonstrated in the latest stages of the phlebogram. The order of venous emptying is also variable. The sphenoidal and occipital subgroups often disappear earlier than the frontal and rolandic, while the parietal veins and the deep curve, together with the vena septi pellucidi, often remain well demonstrated till the end of the phlebogram. In 30 per cent of cases the deep venous curve was the only phenomenon in the last one or two films.

Routine Serial Group. It obviously was impossible to obtain detailed information as to the order of venous filling and emptying from a study of the angiograms belonging to this series. However, out of the 220 cases, 67 showed evidence of filling of the superficial veins first, in 6 the deep veins were the first to fill, while in the remaining 147 cases no evidence of either system filling before the other could be demonstrated. It is almost certain that many of the cases in the last group were not caught in the correct angiographic phase to prove that their superficial veins had actually filled before the deep ones. Fig. 2 is a graphic representation of the ratio between these three groups. Although the whole length of the phlebographic phase usually is not demonstrated in routine serial films, evidence of persistent filling of the deep veins (often with vena septi pellucidi) after the disappearance of the superficial veins was found in 22 cases (Fig. 3). In no case was there evidence that the deep veins were the first to empty.

Inferior Sagittal Sinus (ISS). This vessel deserves special consideration because of the fact that some authorities,7,10,21 as mentioned previously, stated that it is one of the first veins to fill. Greitz,2 however, could not prove such a statement and explained the source of confusion as follows:

"In this material the inferior longitudinal sinus was never the first to fill. Occasionally it filled at the same time as the frontal veins, sometimes at
the same time as the parietal veins, but as a rule somewhat later. This observation is not in agreement with the statements by several authors ... confusion is possible between the inferior longitudinal sinus and the accumulation of contrast medium ... along the surface of the corpus callosum before the inferior longitudinal sinus begins to fill and occasionally in approximately the same position as the sinus. The course of the sinus is, however, higher, particularly in its anterior part. . . . The reason for the accumulation of contrast medium above the corpus callosum is not evident; I do not know in which vessel or vessels the contrast medium is present. It seems to be a summation in the film of contrast medium in a large number of fine vessels, contrasting with the poorly vascularized corpus callosum."

Our observation confirmed that of Greitz. The inferior sagittal sinus failed to be demonstrated at any stage in 25 per cent of both our series. It was the first vein to fill in only 1 case out of the combined series. In the rapid serial films in which the inferior sagittal sinus could be demonstrated, that vessel was found to fill in approximately the same time as the deep venous curve and to empty at a distinctly early stage in the phlebographic phase (Fig. 1); its span of filling (the total time of its radiological demonstration) is relatively short. We found that two structures easily could be confused radiologically with the inferior sagittal sinus, thus giving a false impression of it being filled early:

(a) The accumulation of contrast medium on the surface of the corpus callosum observed by Greitz (Fig. 4).

(b) The posterior part of the anterior cerebral artery. Towards the end of the arterial phase, when only the distal parts of the main arterial branches are seen, the distal segment of the anterior cerebral artery, sometimes having so oblique a course as to be directed downwards and backwards, may be mistaken easily for the inferior sagittal sinus (Fig. 5).

Significance of Size of Vein. Trying to find out the factor or factors determining the appearance and disappearance of one vein or a group of veins before the others, we came to an important conclusion: the larger the size of its vascular lumen, the earlier does a vein fill. This may be because of the fact that a thick vein will carry in its lumen, at a given time, a sufficient "total amount" (not a concentration) of the radio-opaque material for radiological demonstration before such a stage is reached by a thin vessel. The parietal veins often are larger than the frontal veins, and the latter larger than the occipital veins; hence their corresponding order of appear-

**Fig. 3.** Deep venous curve and vena septi pellucidi persisting after disappearance of all other veins.

Note clear demonstration of tributaries of vena septi pellucidi.
Fig. 4. Double demonstration of ISS (upper curve) and accumulation of contrast medium on surface of corpus callosum described by Greitz (lower curve). It is clear how the latter could be mistaken for the ISS, in case this sinus is not demonstrated.

Fig. 5. MA and LA subphases of a case showing how the posterior segment of anterior cerebral artery could be easily mistaken in the LA subphase for an “early” ISS.

Fig. 6. MA and MV subphases of a case showing an abnormally huge ISS. It was the first vein to be demonstrated in the MA subphase.
ance. Moreover, it is not a coincidence that in the only case in our series in which the inferior sagittal sinus was the first to fill, this vessel was of abnormally large size (Fig. 6). On the other hand, we do not claim that this factor is the only one, or even the most important one, governing the order of radiological demonstration of veins. Other anatomical and physiological factors do play an important role in such phenomena as the late appearance of the vena septi pellucidi or the delayed emptying of the deep veins.

II. FILLING OF VEINS DURING ARTERIAL PHASE

As a further step in our observations, we shall endeavor to discuss the radiological representation of veins during the arterial phase of angiography.

Moniz 8 postulated the presence of a phase during cerebral angiography, in between the arteriogram and the venogram of the first phase, during which “no vessels could be demonstrated.” He called it the capillary phase. Wickbom 28 stated that “First the small superficial veins are filled and appear as short vessels, mainly radiating toward the cerebral convexity. These vessels are often visible already on a somewhat late projection of the arterial phase.” Gvozdanović 29 and Lindgren 30 denounced the expression of the capillary phase and substituted it by what they termed the arteriovenous phase, thus emphasizing the fact that vascular elements always could be demonstrated during such a phase. Tönns and Schiefer 31 drew attention to the fact that the termination of the arterial phase and the beginning of the venous phase do not take place simultaneously and uniformly all over the cerebral hemispheres; but proceed from before backwards so that a stage is reached in which veins start to fill up in the anterior region while the terminal parts of the cerebral arteries are still demonstrated back in the occipital area. A true capillary phase could be demonstrated in 6 of our 34 rapid serial angiograms, and 12 of our 220 routine serial ones.

In an attempt to give descriptive terms to the single films obtained by serial angiography, the following scheme of classifying the main phases into seven subphases will be employed:

1. Early arterial phase (EA): The carotid siphon, the stems of the two (or three) cerebral arteries and their primary subdivisions are demonstrated.

2. Middle arterial phase (MA): A full representation of the arterial tree.

3. Late arterial phase (LA): Only the peripheral arterial tree is represented. The carotid siphon together with the main arterial stems have disappeared. To put it in the form of an equation, \( LA = MA - EA \).

4. Capillary phase (Cp): Though a true capillary phase actually may be very rare, we could find in our series a few films which, because of a lack of any vascular details, could not be classified under one or the other of the two bordering phases.

5. Early venous phase (EV): Incomplete appearance of the venous system with its accompanying multitudes of thready tributaries.

6. Middle venous phase (MV): A more “complete, pure and dense” representation of the venous system. The field is more clear because of the disappearance of the minor tributaries. The venous sinuses may partly begin to fill in this phase.

7. Late venous phase (LV): Full representation of the venous sinuses, often together with the deep system. The superficial system often begins to fade out or has already emptied during this stage.

This classification is an arbitrary one, since no hard and fast borders could be placed between the various subphases and sometimes it is difficult to put a certain film under one of them. Fig. 7 shows the various combinations as well as the total incidence of these subphases in our series of 220 routine 4-film serial angiograms.

Rapid Serial Cases. Table 3 shows the comparative case and percentage incidence of the appearance of veins in the arterial subphases as well as in the venous phase.

The obvious conclusion drawn from the study of this series is the fact that veins could be demonstrated in at least 53 per cent
of cases while the arteries were still evident. In 2 cases (6 per cent) there was evidence of veins (of the parietal subgroup in both cases) during the midarterial subphase.

Routine Serial Cases. Table 4 illustrates the comparative case and percentage incidence of the representation of veins in the arterial subphases as compared to their incidence in the venous phase.

Again, the main inference gained from Table 4 is the fact that in at least 26 per cent of routine serial angiograms veins make their first appearance while arteries are still being demonstrated. Out of the 11 cases in which the veins made their first appearance as early as the midarterial subphase, in 10 instances these veins belonged to the ascending superficial group and only once was the inferior sagittal sinus the first vein to appear. The veins that appeared first in the 47 cases during the late arterial subphase were as follows: 33 times, ascending superficial group, 10 times, deep and superficial groups together, 3 times, inferior sagittal sinus, and only once the deep venous curve (Figs. 8 and 9).

Role of Age. The age limits of our patients in the combined series were 5 years and 92 years. The appearance of veins during the arterial phase could be demonstrated at all ages. However, the incidence was found to be relatively higher in the younger age groups; so that the decade of highest incidence was that between 5 and 15 years of age. The rapid cerebral circulation in infancy and childhood is certainly the underlying explanation.

Role of “Prolonged Injection.” Prolongation or continuation of the intra-arterial injection of contrast medium while the roentgen-ray films are being taken will result in superimposition of the arterial and venous systems on the same film. It is clear that in these cases, as the first segment of the intravascular column of contrast medium has already reached the veins, the proximal part is still occupying the stems of the main arteries. Such a “faulty” technique of injection could be revealed radiologically by the persistence of the carotid siphon in the late arterial subphase. Although we have excluded such films from our series, it is certain that some such examples, that have escaped radiological recognition, are responsible for a certain percentage of the early appearance of veins in our tables.
III. CONCLUSIONS

Having studied the "early appearance of veins" in internal carotid angiography from the relative point of view, i.e., in relation to each other, and from the absolute point of view, i.e., in relation to the arteries, we now shall point out the practical significance of our findings.

1. Comparison of Observations Obtained from Both Series. At first sight a discrepancy may seem to exist between the results drawn from both series. However, careful consideration will reveal the fact that the difference is quantitative and not qualitative. The "quality" of the observations and conclusions obtained from both series is the same, e.g., the order and timing of the appearance of veins, the possible representation of veins in the late arterial and to a lesser extent in the middle arterial subphases, etc. The

Fig. 8. MA subphase of a routine serial case demonstrating early appearance of superficial veins. No deep veins.

Fig. 9. LA subphase demonstrating early filling of frontal veins.
quantitative difference is shown in the fact that the figures drawn from the routine serial series are always low as compared to those taken from the rapid serial series. This, as is previously stated, is ascribable to the fact that, because of the slow succession of films, "early veins" are sometimes missed in the former series. It is therefore our conclusion that early veins, both physiological and pathological, could be demonstrated in at least 50 per cent of cases by the routine technique. If this technique failed to demonstrate early veins in a case suspected to manifest such a phenomenon, the rapid serial method should be tried.

2. "Physiological" and "Pathological" Early Veins. The crucial question to be asked when one is faced with a film exhibiting early veins is: are these veins physiological or pathological? With a background of the findings we have already embarked upon in the present work, certain conclusions will be given in an attempt to guide one to an answer to such a question.

(i) Veins appearing in the early arterial subphase are always pathological.

(ii) Veins appearing in the middle arterial subphase: (a) If they are members of the superficial group they are probably pathological, but may be physiological. (b) If they are the deep veins, they are almost always pathological.

3. Veins Appearing in the Late Arterial Subphase. These usually are physiological but may be pathological. In favor of the pathological nature of a vein first demonstrated in the late arterial subphase are the following:

(a) A thin vein appearing before neighboring "thicker" veins.

(b) An occipital vein or the vena septi pellucidi appearing earlier than other veins (parietal or frontal veins).

(c) A segregated early appearance of the deep venous curve or one of its components (only suggestive).

SUMMARY
The order of filling and emptying of cerebral veins is studied in detail proving the tendency of the superficial veins to fill and empty earlier than the deep ones. A study of the appearance of veins during the arterial phase of angiography proved that such an occurrence takes place in about half the rapid serial angiograms and a quarter of the routine serial angiograms. A discussion on the differentiation between physiological and pathological early veins is given.

REFERENCES


