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Diagnostic and Therapeutic Consequences of Repeat Brain Imaging and Follow-up Vascular Imaging in Stroke Patients

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BACKGROUND AND PURPOSE: **Recently, the diagnostic and therapeutic importance of repeat radiologic imaging in stroke patients has been questioned. The aim of this study was to show the therapeutic and diagnostic consequences of both repeat brain imaging and follow-up vascular imaging in this group of patients.**

METHODS: **Neuroradiologic images and reports as well as clinical records of 317 patients (209 men and 108 women; mean age, 63 years) were reviewed retrospectively to determine the number of modifications made to the diagnosis and therapeutic regimen and to the classification of neuroradiologic findings.**

RESULTS: **Two hundred thirty-eight repeat imaging procedures were performed in 171 patients. Of these, 76 were vascular imaging examinations (11 CT angiograms, 13 MR angiograms, 52 digital subtraction angiograms) and 162 were cross-sectional brain imaging studies (54 MR images, 108 CT scans). Forty of the 76 vascular imaging procedures and 77 of the 162 repeat cross-sectional brain imaging studies led to important diagnostic modifications with consequences for the patients' therapy and prognosis.**

CONCLUSION: **Our study establishes that vascular imaging methods as well as cross-sectional brain imaging used as repeat imaging procedures in stroke patients can have important diagnostic and therapeutic consequences. We believe that repeat imaging in selected subgroups will be cost-effective.**

Clinical signs of stroke usually prompt the neurologist to pursue radiologic imaging. The most frequently used radiologic tool in the primary diagnosis of stroke is CT, as it allows the physician to distinguish cerebral ischemia from intracerebral hemorrhage and further aids in the differentiation of embolic, hemodynamic, and lacunar infarction. However, a diagnosis may not be possible on the basis of the first CT study, and a repeat imaging examination may be helpful to confirm or modify the clinical diagnosis. A different mode of imaging, such as CT angiography, MR imaging, or digital subtraction angiography (DSA) may also lead to further information about the pathophysiological basis of the patient's state, thus enabling new therapeutic approaches. Moreover, worsening of the patient's neurologic status ought to prompt repeat imaging in order to initiate appropriate therapeutic steps for possible complications, such as edema, hemorrhagic transformation, or hydrocephalus.

Nevertheless, a recent study by Schneider et al (1) reported no changes in diagnosis after repeat imaging, and the therapeutic regimen was changed (by discontinuing aspirin) in only two of 82 cases. These authors therefore questioned the utility of repeat brain imaging in stroke patients. In this time of pronounced cost containment, such statements could lead to situations in which repeat radiologic imaging would not be reimbursed in patients with stroke. However, the study by Schneider et al was conducted with a small patient population, and no aggressive intervention, such as lysis or hemicraniectomy, was reported.

As practitioners in an academic stroke center with an emphasis on early intervention, our clinical experience suggests a much higher utility for repeat imaging in patients with cerebrovascular disease. Our patient population and our therapeutic strategies appear to be quite different from those reported in Schneider's study. We therefore reviewed the radiologic and neurologic records of the patients admitted to our stroke unit over a period of 12 months to determine the number of modifications

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TABLE 1: Indications for repeat imaging

Indication	No. (%) of Procedures (of 238 Total Repeat Studies)
Routine follow-up	128 (54)
Negative findings on prior study	32 (13)
Worsening of neurologic status	23 (10)
Vascular stenosis on Doppler sonogram	38 (16)
Other	17 (7)

made to the diagnosis and therapeutic regimen and to the classification of neuroradiologic findings.

Methods

Neuroradiologic images and reports as well as neurologic records of all patients admitted to our neurology service from July 1, 1995, to June 30, 1996, were reviewed. This period was chosen because no clinical studies demanding repeat imaging were conducted during that time. All patients with acute signs and symptoms of stroke in this time period who underwent neuroradiologic imaging were included in the study. There were no age limits. All neuroradiologic imaging procedures recorded were performed in the acute stage of stroke.

The indication for each imaging procedure was recorded. Diagnostic and therapeutic changes were assessed after each imaging procedure. Therapeutic categories included lysis, full heparinization, partial heparinization, medication with inhibitors of platelet aggregation, carotid thromboendarterectomy (TEA), decompressive craniectomy, placement of a CSF shunt, and antiedema therapy. Diagnostic categories included embolic, lacunar, and hemodynamic infarction; dissection of the carotid or vertebral artery; thrombosis of the basilar artery; stenosis of the carotid artery (other than dissection); vascular malformation; vasculitis; and cerebral neoplasm.

The number and type of imaging procedures performed were recorded. The two different entities of vascular imaging and cross-sectional brain imaging were assessed separately.

Results

Three hundred seventeen patients with clinical signs and symptoms of stroke were admitted to our neurology service between July 1, 1995, and June 30, 1996. Two hundred nine were men and 108 were women. The mean age was 63 years, and the mean length of hospitalization was 10.8 days. In all, 238 repeat imaging procedures were performed in 171 patients (54%); 121 patients had two imaging examinations, 33 patients had three, and 17 patients had four. Seventy-six (32%) of the repeat procedures consisted of vascular imaging studies (11 CT angiograms, 13 MR angiograms, and 52 digital subtraction angiograms) and 162 (68%) were cross-sectional brain imaging studies (108 CT scans, 54 MR images). There was a tendency toward the use of MR imaging, MR angiography, and DSA as a repeat imaging procedure rather than as the initial diagnostic procedure. Indications for the 238 repeat imaging procedures are listed in Table 1. Of the 128 *routine* follow-up studies listed, 35 (28%) led to a modification in the diagnosis; in 56 cases (44%), the therapeutic regimen was modified after a routine imaging procedure. Modification of the diagnosis was made in 40 (53%) of 74 cases in which vascular imaging methods were used as the repeat imaging study. Thus, nine of 11 CT angiograms, three of 13 MR angiograms, and 28 of 52 digital subtraction angiograms obtained as repeat imaging studies led to a diagnostic modification. In comparison, 77 of the 162 repeat cross-sectional imaging methods led to a diagnostic modification: 49 of 108 CT scans and 28 of 54 MR images. Thirty of 76 repeat vascular imaging procedures led to a therapeutic modification (three of 11 CT angiograms, five of 13 MR angiograms, 46 of 52 digital subtraction angiograms), whereas 107 of 162 repeat cross-sectional brain imaging studies led to a change in the therapeutic regimen.

Tables 2 and 3 give a detailed listing of diagnostic and therapeutic modifications related to the respective imaging procedures. Repeat cross-sectional imaging was especially useful in detecting infratentorial infarction, in classifying the type of infarction, and in identifying complications.

In 40 of 238 repeat imaging procedures, the classification between embolic and lacunar infarction could only be achieved by repeat imaging. Of these, 30 were classified as embolic infarction and 10 as lacunar infarction. Repeat CT led to the final diagnosis in 23 patients; repeat MR in 17 patients. In seven of 10 patients with lacunar infarction, antihypertensive therapy was subsequently initiated.

In eight repeat cross-sectional imaging procedures, an infratentorial infarction was diagnosed that could not be discerned previously. In six of these cases, MR imaging led to the final diagnosis of infratentorial infarction. In 11 repeat cross-sectional imaging procedures, a hemodynamic infarction was diagnosed.

Significant edema requiring therapeutic intervention was diagnosed in 10 of the 238 repeat imaging procedures, leading to the initiation of antiedema therapy in nine cases and to decompressive hemicraniectomy in one case. Hydrocephalus requiring therapeutic intervention was diagnosed in two of the repeat cross-sectional imaging procedures, leading to the surgical placement of a CSF shunt in both cases. Parenchymal hemorrhage requiring therapeutic intervention was diagnosed in one repeat imaging procedure, leading to surgical removal of the hematoma. Hemorrhagic transformation of the ischemic area was diagnosed in four repeat imaging procedures, leading to subsequent withdrawal of anticoagulation therapy.

Vascular imaging methods applied as a repeat imaging method were especially valuable for the detection of carotid stenosis and underlying vascular malformations. In 33 vascular imaging procedures, significant carotid stenosis was diagnosed (26 at DSA, seven at CT angiography), leading to carotid TEA in 21 cases. Carotid dissection was diagnosed in two repeat imaging procedures, once at MR angiography and once at DSA. An aneurysm was diagnosed in two repeat procedures; in one case with MR angiography and in the other with

TABLE 2: Modification of diagnosis or detection of complication after repeat imaging

	Cross-Sectional Imaging		Vascular Imaging		
	CT	MR	CT Angiography	MR Angiography	Digital Subtraction Angiography
Modification after second imaging					
Embolic infarction	14	8	···	···	···
Lacunar infarction	3	4	···	···	···
Infratentorial infarction	2	4	···	···	···
Hemodynamic infarction	7	1	···	···	···
Carotid stenosis	···	···	3	···	20
Parenchymal hemorrhage	1	···	···	···	···
Hemorrhagic transformation	3	···	···	···	···
Aneurysm	···	···	···	···	1
Vasculitis	···	4	···	···	···
Other vascular malformation	···	1	···	···	···
Significant edema	6	···	···	···	···
Internal hydrocephalus	1	···	···	···	···
Modification after third imaging					
Embolic infarction	2	2	···	···	···
Lacunar infarction	···	3	···	···	···
Infratentorial infarction	···	2	···	···	···
Hemodynamic infarction	3	···	···	···	···
Carotid stenosis	···	···	4	···	5
Hemorrhagic transformation	1	···	···	···	···
Carotid dissection	···	···	···	1	1
Aneurysm	···	1	···	···	···
Significant edema	4	···	···	···	···
Internal hydrocephalus	1	···	···	···	···
Modification after fourth imaging					
Embolic infarction	1	···	···	···	···
Carotid stenosis	···	···	···	···	1

TABLE 3: Indications for therapeutic modification after respective repeat imaging procedures

	Cross-Sectional Imaging		Vascular Imaging		
	CT	MR	CT Angiography	MR Angiography	Digital Subtraction Angiography
Modification after second imaging					
Carotid TEA	1	1	···	···	15
Antiedema therapy	5	···	···	···	···
CSF shunt	1	···	···	···	···
Hemicraniectomy	1	···	···	···	···
Surgical removal of hematoma	1	···	···	···	···
Corticosteroids	···	4	···	···	···
Antihypertensive therapy	2	3	···	···	···
Initiation of anticoagulation	33	26	1	3	7
Withdrawal of anticoagulation	5	6	···	···	15
Modification after third imaging					
Carotid TEA	···	···	1	···	3
Antiedema therapy	4	···	···	···	···
CSF shunt	1	···	···	···	···
Antihypertensive therapy	···	2	···	···	···
Initiation of anticoagulation	7	2	1	···	2
Withdrawal of anticoagulation	1	···	···	1	2
Modification after fourth imaging					
Initiation of anticoagulation	2	···	···	1	2

Note.—TEA indicates thromboendarterectomy.

DSA. In total, both vascular imaging and cross-sectional brain imaging methods used as repeat studies in patients with stroke had an important impact on diagnostic and therapeutic reasoning. Cross-sectional brain imaging was especially valuable in the detection of complications and in the classification of the type of infarction, whereas vascular imaging was especially helpful in the detection of an underlying vascular malformation and of carotid stenosis.

Discussion

There is an increasing tendency toward cost containment and quality control in medicine. Expenses are to be reduced while quality is to remain high. Set reimbursement schemes for diagnostic categories are becoming more common. In a recently published study, Schneider et al (1) reported no diagnostic or therapeutic consequences of repeat imaging in patients with signs of cerebral ischemia. These results would eventually suggest that repeat radiologic imaging procedures should not be reimbursed for patients with a diagnosis of stroke. However, their study was conducted with a small patient population, and no aggressive intervention, such as lysis or hemicraniectomy, was reported.

In our stroke center, early aggressive therapy, such as thrombolysis or hemicraniectomy, is being used with increasing frequency. The time period of our retrospective study was chosen to avoid ongoing clinical studies that would require repeat imaging. However, comparatively few patients have undergone systemic lysis during that time. With the results of the European Cooperative Acute Stroke Study (ECASS) and an American study on the use of tissue plasminogen activator in stroke now published, and phase II of ECASS in progress, substantial evidence has accumulated of a beneficial therapeutic effect of systemic lysis that outweighs the risks (2–4). We assessed the diagnostic and therapeutic consequences of repeat cross-sectional brain imaging, as done by Schneider et al (1), and of vascular imaging, such as CT angiography, MR angiography, and digital subtraction angiography, as repeat imaging methods. Our findings showed that repeat cross-sectional brain imaging is often helpful in the detection of complications of therapy, thus indicating the need for a change in the therapeutic regimen.

After the application of thrombolytic therapy, the diagnosis of possible hemorrhagic transformation and parenchymal hemorrhage is crucial for the patient's outcome. Differentiation between hemorrhagic transformation and an increase of the ischemic area in a patient with known cerebral ischemia and worsening neurologic status can only be achieved with radiologic imaging. In patients with intracerebral hemorrhage, systemic lysis and/or anticoagulants have to be discontinued and, in severe hemorrhage, surgical procedures must be initiated. In case of increasing cerebral ischemia, however, anticoagulation should be continued and an appropriate workup to uncover the causes of the ischemia must be initiated. Thus, repeat imaging in a stroke patient with worsening neurologic status may be life-saving, especially if thrombolysis is administered.

Repeat cross-sectional brain imaging is important not only in patients selected for thrombolytic therapy but also for the early detection of a so-called malignant infarction accompanied by extensive edema, which may lead to increasing neurologic damage and even to death from brain-stem compression. Recent publications have shown that aggressive therapy for malignant cerebral infarction, such as trepanation or hypothermia, leads to a significant increase in survival and a decrease in neurologic impairment (5–8). However, this can only be achieved if treatment is administered early in the evolution of edema (9). Therefore, screening for the development of malignant infarction is crucial for patients with a pattern of ischemia predisposing them to a space-occupying infarction. In our study, 10 of 238 repeat imaging procedures led to the detection of significant edema, enabling early administration of adequate therapy.

In early publications on the role of CT in cerebrovascular diseases, it was reported that abnormalities frequently could not be discerned during the first 48 hours (10, 11). With the advent of advanced CT technology, early signs of cerebral ischemia, such as loss of the insular ribbon, attenuation of the lentiform nucleus, hemispheric sulcal effacement, or the hyperdense middle cerebral artery sign, can now be detected as early as 6 hours after the onset of clinical symptoms and signs (12–14). But even with this improved early diagnosis of cerebral infarction with the use of CT, specific classification of the type of infarction is often not possible initially. Classification of cerebral ischemia into embolic, hemodynamic, or lacunar infarction is crucial, since it has a decisive impact on long-term therapeutic decision making. While the mainstay of treatment for lacunar infarction consists of antihypertensive therapy, a search into the causes of hemodynamic and embolic infarction is crucial for secondary prevention strategies and therapeutic reasoning. Therefore, correct classification of the specific type of cerebral ischemia is of decisive importance for a further, cost-effective diagnostic workup and for a sensible therapeutic regimen—and this classification often can be achieved only after repeat imaging, sometimes also with a different radiologic technique, such as MR imaging. In our study, a distinction between embolic and lacunar infarction could only be achieved by repeat imaging in 40 of the 317 patients examined. Hemodynamic infarction was assessed only by repeat cross-sectional imaging in 11 patients, in all of whom appropriate therapy and/or further diagnostic assessment was subsequently initiated.

When MR imaging is used as a repeat radiologic procedure, it frequently results in the new diagnosis of infratentorial ischemia in patients with previously normal CT findings. It is often of assistance in identifying the exact location of an infratentorial ischemia and also in excluding small vascular malformations or minimal hemorrhage, which could have easily been overlooked in the CT scan. In our study, a repeat radiologic imaging procedure led to the diagnosis of infratentorial infarction in eight of the 238 cases.

Vascular imaging methods, such as MR angiography, CT angiography, and digital subtraction angiography, were especially helpful in the diagnosis of carotid stenosis in patients with hemodynamic infarction. If significant carotid stenosis is found, the patient should be offered carotid TEA, which significantly reduces the chance of repeat ischemia in symptomatic carotid stenosis (15). In 31 patients, significant carotid stenosis was detected when vascular imaging was applied as a repeat imaging procedure; 21 of these patients subsequently underwent carotid TEA. These results suggest the crucial importance of repeat vascular imaging for diagnostic certainty, future therapy, and outcome in patients believed to have had a hemodynamic infarction. Moreover, MR angiography and CT angiography aid in the identification of patients with carotid and vertebral dissection, as they depict both the mural hematoma and the degree of stenosis. The diagnosis of vascular dissection is of importance both for the prognosis and the therapeutic regimen. In our study, carotid dissection was diagnosed after a repeat vascular imaging procedure in two cases.

DSA as a repeat imaging procedure is also indicated if a vascular malformation is suspected on a previous CT or MR study and surgery is being considered as an option. In our study, two aneurysms and one cavernous hemangioma were identified at repeat imaging. In the case of a vascular malformation, diagnostic angiography may even be combined with a therapeutic neuroradiologic intervention. In summary, with increasing therapeutic options at hand, neuroradiologic imaging in patients with cerebral ischemia becomes more important in identifying those in need of specific treatment techniques and in detecting possible complications of the therapy.

Our study showed that both vascular imaging methods and cross-sectional brain imaging studies used as repeat imaging procedures in patients with stroke had an important impact on diagnostic and therapeutic reasoning. Cross-sectional brain imaging was especially valuable in the detection of complications and in the classification of the type of infarction, while vascular imaging was especially helpful in the detection of an underlying vascular malformation and in the detection of carotid stenosis.

Conclusion

Our data suggest that repeat neuroradiologic imaging has an important effect both on diagnostic considerations and on the choice of therapeutic regimen, especially in selected subgroups of patients: 1) Patients in whom no classification of infarction can be established from the initial imaging study should undergo repeat cross-sectional studies, such as CT or MR imaging. 2) Patients with a pattern of infarction predisposing to the evolution of malignant edema should undergo repeat cross-sectional CT to screen for signs of beginning herniation. 3) Patients undergoing aggressive therapy, such as thrombolysis with consecutive anticoagulation, should undergo repeat cross-sectional CT to screen for hemorrhage. 4) Patients in whom carotid or vertebral dissection is suspected should undergo vascular imaging, such as MR angiography or DSA. 5) Patients in whom significant carotid stenosis was suspected on a previous radiologic study should undergo vascular imaging, such as DSA. 6) Patients in whom a vascular malformation was suspected on a previous imaging study should undergo DSA to verify the diagnosis, possibly even combined with an interventional neuroradiologic procedure. We believe that repeat neuroradiologic procedures, both cross-sectional brain imaging and vascular imaging, in these subgroups of patients will prove to be cost-effective, since it will raise diagnostic certainty as well as therapeutic specificity and thus improve the patient's long-term outcome.

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