Cocaine use has increased rapidly over the past few years. This has led to an increase in the number and variety of cocaine-related conditions for which medical attention is sought. Among these have been several cases of intracranial hemorrhage. Four cases reported in the literature and 6 from our own institution are presented here. They represent different diagnoses including hemorrhage from aneurysms and arteriovenous malformations, hemorrhage into a tumor, and spontaneous hemorrhage with no underlying lesion with and without preexisting hypertension. Analysis of these cases suggests that the hypertension induced by cocaine secondary to sympathetic stimulation may be the common factor. Cocaine may also cause arterial spasm. Although the pathophysiology has not been entirely resolved, the clinical significance of this association is clear. Intracranial hemorrhage should be considered in the differential diagnosis whenever a patient presents with an acute alteration in neurologic examination associated with cocaine use. (Stroke 1987;18:712–715)

Cocaine in its varied forms has become increasingly popular as a recreational drug in the past few years. Associated with this increase in the use of cocaine has been an increasing incidence of medical complications including myocardial infarction (MI), spontaneous abortion, and behavioral abnormalities in infants born to mothers using cocaine during pregnancy.2-7

A significant development has been the increasing number of patients presenting with subarachnoid hemorrhage (SAH) or intracerebral hemorrhage (ICH) following cocaine use. There are 4 cases of documented intracranial hemorrhage following cocaine use in the literature; 2 were SAHs and 2 were temporoparietal ICHs.8,9 Both patients with SAH were found to have underlying aneurysms on angiography; 1 had an anterior communicating artery aneurysm, the other a right posterior communicating artery aneurysm. One patient with an intracerebral hematoma was found to have an underlying arteriovenous malformation (AVM); the other had an angio graphic view of the right posterior communicating artery aneurysm. One patient suffering an acute right hemisphere infarct immediately following cocaine use.9 Occlusion of the right posterior cerebral artery and narrowing of the ipsilateral anterior and middle cerebral arteries, but no structural lesion, was seen on angiography. A second patient suffered acute right hemisphere infarction following use of free-base cocaine ("crack").10 Angiography revealed narrowing of the supracallosal right internal carotid artery and cutoff of distal branches. We present here an additional 6 cases with a discussion of the possible pathophysiology.8,9

Reports of Cases

Case 1

A 22-year-old black man presented to an outside hospital 1 day before admission to our service. The patient had been in good health except for a questionable history of hypertension. He admitted to smoking 1 pack of cigarettes per day, social drinking, and occasional smoking of free-base cocaine, but denied other drug use. He had been smoking cocaine when he noted the acute onset of headache and had a seizure, which started in his left leg but generalized and was associated with nausea and vomiting. He was admitted to a local hospital where noncontrast computed tomography (CT) scan revealed diffuse SAH. He was transferred to Bellevue Hospital. Cerebral angiography demonstrated a right posterior communicating artery aneurysm and a small junctional dilatation at the origin of the left posterior communicating artery. The patient remained neurologically intact and underwent uneventful clipping of the right-sided aneurysm 3 days after his SAH. He developed transient left-sided weakness secondary to vasospasm on Day 7 after his SAH, but this rapidly resolved with intravascular volume expansion. The patient was discharged without any neurologic deficit. He returned to his cocaine use, stopped his anticonvulsant regimen, and presented to another hospital 10 months after his first SAH with a left-sided subdural and intraventricular hemorrhage. It was reported that he had either collapsed to the ground, striking his head, and then had a seizure or that he had suffered the seizure and then collapsed. The patient required emergency evacuation of the subdural hematoma and was left in a comatose state with a right hemiparesis. He gradually became more responsive over the following month but suffered another seizure while in the hospital on adequate anticonvulsants. He rapidly became unresponsive, and his craniotomy defect was noted to be bulging. CT scan showed intraventricular and subarachnoid blood with acute hydrocephalus. Emergency ventriculostomy and eventual ventriculopleural shunting was performed, but the patient remained in a persistent vegetative state. Repeat angiography revealed the junctional dilatation on the left side to be slightly enlarged compared with the previous study; no other lesions were found. Due to the patient’s general condition and poor prognosis, no attempt was made to surgically correct this lesion.
Case 2

A 29-year-old black woman who was previously in good health and who was a known intranasal cocaine user was found in the bathroom at her place of employment in a confused and noncommunicative state. She was brought to Bellevue Hospital where she was noted to be mildly hypotensive (pressure 90 mm Hg systolic) and tachycardic. On neurologic examination, she was confused, had 3-mm sluggishly reacting pupils, conjugate eye movements, a moderate right hemiparesis, and a right Babinski reflex. Noncontrast CT scan revealed diffuse and massive subarachnoid blood. The patient’s urine toxicology screen was positive for cocaine. The patient was started on routine management for SAH and gradually improved over 12 hours to answer simple questions, but she remained confused and lethargic with a right hemiparesis. Several hours later, she became acutely unresponsive to verbal stimuli and rapidly developed fixed, dilated pupils, dysconjugate gaze, flaccidity in all extremities, and absence of brainstem reflexes. She died shortly thereafter of intractable cardiac arrhythmia. An autopsy was performed and disclosed a ruptured right posterior communicating artery aneurysm.

Case 3

A 34-year-old black man with a history of hypertension but currently on no medication was observed to have an abrupt change in mental status shortly after injecting himself with the contents of a syringe. He was brought to Bellevue Hospital, where he was noted to have a blood pressure of 210/120. On neurologic examination, he was alternately lethargic and agitated, opening his eyes to loud voice. He would mumble and occasionally speak in sentence fragments but would not consistently answer any questions other than to give his name when asked. His examination was otherwise unremarkable. A urine toxicology screen was positive only for cocaine. Noncontrast CT scan demonstrated blood throughout the ventricular system, mild hydrocephalus, and a small left caudate ICH. The patient’s electrocardiogram (ECG) was remarkable for periods of junctional rhythm with retrograde P waves, high voltage, and inverted T waves in Leads III and AVF. Creatine phosphokinase (CPK) isoenzymes were obtained but were normal. The patient’s mental status gradually improved over the following week, and his blood pressure was medically controlled. The patient’s hemiparesis and field cut resolved with steroids and conservative management. He was discharged 3 weeks after his hemorrhage, with evidence of clot resolution on repeat CT scans. Six weeks later, he again had acute onset of headache and was admitted to an outside hospital, where CT scan revealed recurrent right temporal hemorrhage with surrounding edema. Angiography was again negative, and the patient remained without focal deficit on steroids. Serial CT scans at New York University Hospital continued to show more hemispheric edema than would be expected surrounding a hematoma, and the possibility of hemorrhage into a tumor was considered. The patient did not tolerate tapering of his steroids, and he developed a hemiparesis. He underwent a craniotomy and right temporal lobectomy 3 months after his initial hemorrhage. The pathologic finding was moderate-to-markedly anaplastic astrocytoma with hemorrhage into the tumor. He required further surgical decompression and drainage of a cyst in the tumor bed 1 week later. Postoperatively, he did well but required maintenance steroids. Progressive tumor growth was seen on CT scans prior to radiation therapy, but significant tumor necrosis was noted after the administration of 4,500 cGy whole brain and 1,720 cGy tumor bed irradiation. After completion of radiation therapy, the patient had recurrent tumor growth and eventually died of his disease.

Case 4

A 22-year-old white man with no prior medical history experienced abrupt onset of headache, nausea, vomiting, neck stiffness, and right-sided weakness and numbness while using cocaine intranasally and drinking alcohol. He presented to a local hospital, where a lumbar puncture was performed. The cerebrospinal fluid was found to be bloody, and a CT scan was performed, revealing a left frontal intracerebral hematoma with extension into the lateral ventricle. Angiography was performed, demonstrating a left posterior frontal AVM. The patient was transferred to New York University Hospital. Over the week following his hemorrhage, his hemiparesis gradually improved, but he was left with a moderate cognitive deficit. He underwent a craniotomy for evacuation of the hematoma and resection of the AVM. His postoperative course was uneventful, and he was discharged with a mild residual hemiparesis and a mild memory deficit.

Case 5

A 42-year-old white man was in good health until 1 day before admission, when he experienced the sudden onset of headache while using cocaine. He was brought to the New York University Hospital emergency room, where he was found to have a mild left hemiparesis, homonymous left visual field cut, and confusion. CT scan showed a right posterior temporal intracerebral hematoma with ventricular extension. Angiography failed to demonstrate any lesion. The patient’s hemiparesis and field cut resolved with steroids and conservative management. He was discharged 3 weeks after his hemorrhage, with evidence of clot resolution on repeat CT scans. Six weeks later, he again had acute onset of headache and was admitted to an outside hospital, where CT scan revealed recurrent right temporal hemorrhage with surrounding edema. Angiography was again negative, and the patient remained without focal deficit on steroids. Serial CT scans at New York University Hospital continued to show more hemispheric edema than would be expected surrounding a hematoma, and the possibility of hemorrhage into a tumor was considered. The patient did not tolerate tapering of his steroids, and he developed a hemiparesis. He underwent a craniotomy and right temporal lobectomy 3 months after his initial hemorrhage. The pathologic finding was moderate-to-markedly anaplastic astrocytoma with hemorrhage into the tumor. He required further surgical decompression and drainage of a cyst in the tumor bed 1 week later. Postoperatively, he did well but required maintenance steroids. Progressive tumor growth was seen on CT scans prior to radiation therapy, but significant tumor necrosis was noted after the administration of 4,500 cGy whole brain and 1,720 cGy tumor bed irradiation. After completion of radiation therapy, the patient had recurrent tumor growth and eventually died of his disease.

Case 6

A 51-year-old white man who was well except for mild exertional angina awoke on the day of admission with bifrontal headache and retro-orbital pain. He reportedly had used cocaine intranasally the previous evening. He was admitted to Bellevue Hospital after suffering a grand mal seizure. On admission, the patient had stable vital signs and was without focal neurologic deficit. Noncontrast CT scan disclosed a right
frontal intracerebral hematoma. Shortly thereafter, he developed ventricular arrhythmias requiring treatment with i.v. lidocaine. An ECG obtained at this time revealed recent ischemic changes when compared with previous tracings. The relation of this apparently acute myocardial event to the ICH was unclear. After stabilization, cerebral angiography was performed and failed to demonstrate any lesion. One week after his initial hemorrhage, he suffered a right middle cerebral artery infarct, resulting in a dense left hemiparesis and left hemineglect. He was also found to have recurrent atrial fibrillation associated with mildly elevated cardiac enzymes. Echocardiography and gated blood pool study were performed to evaluate the possibility of emboli from a cardiac source and to examine myocardial function. Both studies were normal. There was persistent evidence of recent ischemia on serial ECGs, and this was believed to be consistent with subendocardial MI. The patient was transferred to the rehabilitation service 3 weeks after his initial hemorrhage, but shortly thereafter he developed refractory atrial fibrillation. He had progressively worsening arrhythmias and was believed to have had another MI. He finally died of uncontrollable ventricular tachycardia and fibrillation 1 month after his initial hemorrhage.

Discussion

The cases of intracranial hemorrhage associated with cocaine use that we have reported here represent a diverse group of diagnoses. To attribute these hemorrhages to one pathophysiologic process is difficult. What is apparent in reviewing our cases and those reported in the literature is that the majority of patients have had an underlying vascular lesion. It would appear that some physiologic change that occurs after cocaine use places increased stress on these lesions.

The transient elevation in systemic blood pressure that occurs following cocaine use is the most likely common factor. This might also explain the occurrence of ICH without an underlying vascular lesion in at least 1 patient who was known to be hypertensive. Cocaine blocks norepinephrine reuptake by neurons, leading to sympathetic hyperactivity and subsequent transient hypertension similar to that seen following amphetamine use. The reported cases of MI following cocaine use in patients with underlying coronary artery disease are believed to be due to a similar mechanism. Decreased reuptake of norepinephrine leads to sensitization of the heart to catecholamines. This in turn leads to increased myocardial oxygen demand, which may outstrip supply.

The etiology of the hemorrhage in our patient with an underlying glioma is less certain. Spontaneous hemorrhages associated with the abnormal vessels found within malignant astrocytomas are not uncommon, and this patient's second hemorrhage was apparently of this nature. Whether cocaine played a role in the initial hemorrhage by causing transient hypertension in the already weak vessels of the tumor bed is unclear.

The finding of narrowed and occluded vessels on angiography in the patients who suffered acute cerebral vascular occlusion following cocaine use suggests that there may be a direct vasospastic effect of cocaine on the blood vessels. This is supported by reports of patients with no underlying coronary artery disease on angiography who suffer MIs following cocaine use. The pattern and progression of these infarcts has suggested a transient occlusion of one or more major coronary arteries by spasm. There is no evidence to date that cocaine causes actual vasculitis such as that believed to be at least partially responsible for the well-known entity of intracranial hemorrhage following recreational amphetamine use in the absence of a pre-existing vascular lesion.

In addition to directly precipitating MI, cocaine may contribute to the cardiac complication associated with SAH. Recent articles have suggested that the ECG changes and dysrhythmias frequently associated with SAH may be due to irritation of the posterior hypothalamus and subsequent hyperactivity of the sympathetic nervous system. In patients who have died after SAH and who exhibited cardiac dysrhythmias and/or ECG changes, subendocardial myonecrosis and elevated serum CPK-MB isoenzymes have regularly been found. The combined effects of cocaine and the subarachnoid blood itself on the adrenergic system may increase the likelihood of cardiac injury in patients suffering SAH following cocaine use. Indeed, 1 of our patients succumbed to refractory arrhythmias shortly after her hemorrhage, and another was noted to have suffered an acute MI.

Up to 25% of all sudden deaths following cocaine use are from undetermined causes, and these deaths are often associated with preterminal seizures and respiratory arrest. What percent of these deaths might be due to intracranial hemorrhage and/or cardiac arrhythmia demands serious consideration.

Another concern is the recent increase in popularity of highly purified free-base forms of cocaine, such as that referred to as "crack." With the exception of the case reported above, no specific conditions related to the use of this substance have been reported, but as its use spreads, more will be learned about potential side effects.

With cocaine use continuing to spread, there will almost certainly be more patients seeking medical assistance for use-related conditions. It has become apparent that intracranial hemorrhage from a variety of causes must be considered in the differential diagnosis of patients who present with sudden alteration in neurologic function following cocaine use.

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