Arterial dissections of penetrating cerebral arteries causing hypertension-induced cerebral hemorrhage

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Object. For the past 130 years, it has been believed that hypertension-induced cerebral hemorrhages are the result of ruptures of microaneurysms or ruptures of arteries that have degenerative changes. The majority of previous investigations have focused on autopsied brain. In this study, the authors attempted to verify the cause of hypertension-induced cerebral hemorrhage by using surgical specimens of the penetrating arteries responsible for the hemorrhages.

Methods. Between 1997 and 1999, the authors performed pathological studies in surgical specimens of lenticulostriate arteries that had been confirmed during microsurgery to be the cause of hypertension-induced hemorrhage of the putamen. Nineteen lenticulostriate arteries were collected from 12 patients. Fifteen of these arteries were verified as the pathological causes of hemorrhage. They included six arterial dissections, six arterial ruptures with substantial degenerative changes, and three arterial ruptures with few degenerative changes. The pathological findings in the lenticulostriate artery dissections were similar to those of typical arterial dissections in major cerebral arteries.

Conclusions. To the best of the authors’ knowledge, arterial dissections of lenticulostriate arteries have not been identified as a cause of hypertension-induced cerebral hemorrhages. When penetrating arteries are included as causative vessels, cerebral arterial dissections may be much more common than previously thought.

KEY WORDS • hypertension-induced cerebral hemorrhage • arterial dissection • penetrating artery

Materials and Methods

Between 1997 and 1999, we performed pathological studies in penetrating arteries that were responsible for hypertension-induced cerebral hemorrhages.

Nineteen lenticulostriate arteries verified to have caused putamen hemorrhages were collected from 12 patients during microsurgery, including specimens obtained at the bleeding site. The bleeding site was determined either by findings of active intraoperative bleeding or by identifying a portion of artery covered with a clot that was more solid than the hematoma itself. We took special care in the management of specimens to avoid surgical artifacts. With the aid of the operating microscope, we used a gentle and fine suction procedure while avoiding direct contact with the bleeding site. We cut the affected arteries 5 to 10 mm from the bleeding site, a distance deemed sufficient to obtain a normal portion as well. The sampled arteries were fixed in 10% formalin and embedded in a paraffin block. Each artery was cut serially every 5 to 10 μm and the slices were stained with hematoxylin and eosin and with elastica van Gieson. Some significant slices were stained using the Movat pentachrome method as well.

Results

The 12 patients from whom specimens were obtained had undergone surgery within 2 days after onset of hemorrhage. The patients' ages ranged from 46 to 84 years. The maximum diameters of the hematomas ranged from 4 to 6.8 cm. All patients had a history of hypertension.

Abbreviation used in this paper: IEL = internal elastic lamina.
Pathological Findings

The diameters of the sampled penetrating arteries ranged from 100 to 700 μm. Atherosclerosis was not prominent in any specimen. The causes of bleeding were verified in 15 of the 19 arteries. They included arterial dissection in six vascular specimens; rupture of an artery with substantial degenerative changes, including microaneurysm formation in six specimens; and rupture of an artery with few degenerative changes in three specimens.

Arterial Dissections

Ruptures of arterial dissections were observed in six cases. In all of these cases, disruption of the IEL and formation of a pseudolumen between the IEL and the media and/or between the media and the adventitia were observed in a considerable number of serial slices collected from the bleeding site (Fig. 1 upper). Even at the ends of arterial dissection, the pseudolumen communicated with the true lumen through the disrupted IEL (Fig. 1 center). There was no remarkable degeneration or necrotic change in the arteries responsible for hemorrhages. The pathological features of arterial dissection are illustrated in Fig. 1 lower.

Microaneurysms and Ruptures of Arteries With Substantial Degenerative Changes

Ruptures of degenerated arteries were observed in six cases. In each of these arteries, the IEL was fragmented or almost missing and the media was remarkably thinned and degenerated (Fig. 2 upper). Aneurysm formation was observed in a portion of ruptured arterial wall in one case (Fig. 2 center).

Ruptured Arteries With Few Degenerative Changes

Ruptures with few degenerative changes were observed in three arteries. In each of these arteries, we observed a ruptured portion, but no indication of microaneurysm formation prior to bleeding. Degeneration of the IEL and thinning of the media were unremarkable (Fig. 2 lower).

Discussion

In 1868, Charcot and Bouchard observed microaneurysms of penetrating arteries in an autopsied brain and suggested that they might be responsible for hypertension-induced cerebral hemorrhage. Since then, many reports have supported this hypothesis. However, a substantial number of investigators have insisted that hypertension-induced cerebral hemorrhages are caused by ruptures of arteries in which there was microaneurysm formation prior to bleeding. Previously described pathological findings in ruptured arteries have included formations of pseudoaneurysms called “bleeding globes,” hyalinization of the arterial wall, angionecrosis, and degeneration of media. On the other hand, in many ruptured arteries there have been no abnormalities around the ruptured site. The majority of pathological studies performed to identify the cause of hypertension-induced cerebral hemorrhage have focused on autopsied brain. In fact, to our knowledge, there have been only two previous investigations in which surgical specimens have been used for this purpose. In one of these studies, Takebayashi and colleagues found one ruptured microaneurysm and 11 ruptured arteries in 11 patients who had been surgically treated. In the other study, microaneurysm and rupture of the artery were not differentiated.
Arterial dissections of penetrating cerebral arteries

one ruptured artery is usually identified because a substantial number of arteries bleed secondarily due to the mechanical tension of the expanding hematoma. In surgical cases, it is easier to locate which arteries are primarily responsible for the hemorrhage because they are usually larger than arteries that are secondarily responsible and are found in the midst of the hematomas. However, we could not differentiate between primary and secondary responsible arteries in some of our patients. As a result, we had to collect two arteries from the same patient in some instances. Otherwise, we assumed that we had collected two separate ends of a primary bleeding artery. Since Charcot and Bouchard’s study performed more than 130 years ago, there has been a long-standing controversy regarding the mechanism of hypertension-induced cerebral hemorrhage. Notwithstanding, no investigators before us have been prompted to examine cerebral arterial dissection of penetrating arteries as a cause of cerebral hemorrhage.

Arterial Dissections of Penetrating Arteries

The primary mechanism of arterial dissection of major cerebral arteries is assumed to be disruption of the weakened IEL caused by hemodynamic stress. The IEL is the strongest structure of the cerebral arterial wall. It has been demonstrated that normal IEL of cerebral arteries can withstand a blood pressure of 600 mm Hg without bulging. Penetrating arteries and other cerebral arteries are characterized histologically by a single elastic lamina, the IEL, containing most of the elastin in the arterial wall. The disruption of the IEL and formation of a pseudolumen in the arterial dissections of penetrating arteries, which were verified in the present study, were very similar to those detected in arterial dissections of major cerebral arteries.

A “dissecting aneurysm” has been defined as “a lesion produced by penetration of the circulating blood into the substance of the wall of a vessel with subsequent extension of the effused blood for a varying distance between its layers.” In the present series, some cases of ruptured artery or microaneurysm demonstrated dissections between the IEL and media in only a limited number of slices that originated close to the bleeding sites (Fig. 2 center and lower). These were assumed to be secondary dissections generated at the time of rupture. On the other hand, the pseudolumen of an “arterial dissection” assumed to be the primary cause of the hemorrhage extended for a considerable distance from the rupture point, which fits well within the definition given earlier.

In microelectroscopic studies, the IEL is depicted as a sheet perforated by many holes. It has been demonstrated that hemodynamic stress markedly enlarges the sizes of the holes and weakens the structure of the IEL. When hemodynamic stress is exerted, it is thus assumed to extend through the dilated holes and directly influence the state of the media.

Some groups have stressed that degeneration and necrosis of the media are primary factors causing microaneurysms or ruptures of the artery. They have noted that invasion of some plasma elements through the IEL may enhance medial degeneration. However, medial degeneration is often preceded by degeneration or disruption of the IEL.

Arterial dissections in major cerebral arteries as the cause of subarachnoid hemorrhage are generally reported to occur infrequently, accounting for only 3.2% of all aneurysmal subarachnoid hemorrhages. However, as was demonstrated in the present study, arterial dissections may be a much more common cause of cerebral hemorrhage, because they are assumed to occur more frequently in penetrating arteries.

Conclusions

We assume that there are several substantial mech-
anisms of hypertension-induced cerebral hemorrhage. Acute disruption of the somewhat weakened IEL may cause rupture of the artery or arterial dissection. On the other hand, disruption of the microaneurysm induced by the chronic degenerated weakness of the IEL may also cause cerebral hemorrhage.

References

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