TRANSIENTERIAL HERNIATION is a well known complication of expanding supratentorial lesions with resulting clinical impairment of consciousness and brain stem functions, and often culminating in death.1-5 Expanding supratentorial lesions are frequently followed by secondary brain stem herniation.6 The risk of secondary brain stem herniation has been regarded as a function of the growth velocity of the primary space occupying lesion, as well as of the volume which the lesion ultimately achieves.7,10 It is assumed that a quickly expanding lesion, such as cerebral hemorrhage, will produce a more rapid caudal displacement of the brain stem causing secondary brain stem herniation, than a slower growing lesion such as infarction with concomitant edema.5 In early death following acute cerebrovascular lesions, symptoms of cerebral herniation are seen, and it is generally accepted that herniation often is a significant factor contributing to death. The aim of the present study was to evaluate these aspects by the analysis of a large autopsy material with recent cerebral hemorrhage, infarction or ruptured aneurysm and to assess the lesions frequency, time of occurrence, and age and sex distribution.

Material and Methods
Among all patients who had brain autopsy at Rigshospitalet from January 1971 through August 1982, 435 had recent cerebral hemorrhage, infarction or ruptured cerebral aneurysm. Among all patients with recent cerebral hemorrhage, infarction or ruptured cerebral aneurysm there was no significant difference in its distribution between the sexes. Secondary occipital lobe infarction was present in 3.5% of the patients. It is concluded that secondary brain stem hemorrhage is a common major contribution to the cause of death in stroke.

Secondary Brain Stem Hemorrhage in Stroke
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SUMMARY The occurrence of secondary brain stem hemorrhage was studied in 435 autopsies from patients with recent cerebral hemorrhage, infarction or ruptured cerebral aneurysms. The frequency of secondary brain stem hemorrhage was found to be 45% in cerebral hemorrhage, 15% in cerebral infarction, and 36% in ruptured aneurysms. In the majority of cases the secondary brain stem hemorrhage occurred a few days after the onset of cerebral hemorrhage or infarction. Ruptured aneurysms showed a more widespread temporal distribution of secondary brain stem hemorrhage.

The median survival time was 2 days in cases of cerebral hemorrhage, 4 days in ruptured aneurysm and 4 days in cerebral infarction. The frequency of secondary brain stem hemorrhage was significantly lower in patients younger than 20 years. No significant difference was found in its distribution between the sexes. Secondary occipital lobe infarction was present in 3.5% of the patients. It is concluded that secondary brain stem hemorrhage is a common major contribution to the cause of death in stroke.

Length of Survival
Hemorrhage
The median survival time was 2 days (fig. 1). The frequency of secondary brain stem hemorrhage varied considerably according to the character of the precipitating supratentorial lesion (table 1). In cerebral hemorrhage, the frequency was 45%, in ruptured congenital aneurysm 36%, and in cerebral infarction only 15%. However, the frequency of secondary brain stem hemorrhage was 29% in those cases which showed thrombosis and infarction in the internal carotid artery and its branches. In cases of infarction without demonstrated thrombosis in these vessels the frequency was only 1.2%.

Ruptured Aneurysms
The median survival time was 4 days (fig. 2). Unlike cerebral hemorrhage and infarction there was no...
tendency towards an early secondary brain stem hemorrhage. The greater part of the ruptured aneurysms were localised on the middle cerebral arteries but their exact localisation did not affect frequency of the secondary brain stem hemorrhage.

Infarction

The median survival time was 4 days (fig. 3). The frequency of secondary brain stem hemorrhage was significantly higher during the first 4 days than during the following days ($p = 0.0001$). Up to day 30, the survival time in cases of infarction with demonstrated thrombosis in the intracranial vessels was identical with the distribution in those without thrombosis. After day 31, there was a higher frequency of death in cases of infarction without demonstrated thrombosis (fig. 3).

Relation Between Secondary Brain Stem Hemorrhage, Sex and Age

Table 2 shows a slight tendency towards a higher frequency of secondary brain stem hemorrhage in women, a difference which is statistically non-significant.

No instances of secondary brain stem hemorrhage were encountered in 11 patients who were younger than 20 years (table 3). In all other age groups secondary brain stem hemorrhage occurred with the same frequency, although there was a tendency to a somewhat higher frequency in the age groups between 40 and 70 years. The difference between the patients under 20 years and those belonging to other age groups was statistically significant ($p = 0.042$).

Secondary Occipital Infarcts

Secondary occipital infarcts were found in 15 patients (3, 5%) who died relatively late (table 4). Six had cerebral hemorrhage, 7 had ruptured aneurysm, and only 2 had cerebral infarction. No correlation was found between occipital lobe infarction and secondary brain hemorrhage.
SECONDARY BRAIN STEM HEMORRHAGE IN STROKE/Nedergaard et al.

Cerebral infarction without intracranial thrombosis

Cerebral infarction with intracranial thrombosis

![Graphs showing distribution of cases and survival days](https://example.com/graph.png)

FIGURE 3. Distribution of all deaths according to number of days after cerebral infarction. Striped areas represent secondary brain stem hemorrhage.

Discussion

Supratentorial space occupying lesions may cause transtentorial caudal herniation with downward displacement through the tentorial notch of parts of the hemispheres, which compress the diencephalon and the adjoining midbrain. Neuropathological examination of such cases shows cerebral grooving in the vicinity of the tentorial notch resulting from compression against the free edge of the tentorium cerebelli.

However, grooves are often found in the uncus of brains free from overt disease, and the range of normal variation is not defined. Secondary brain stem hemorrhage always represents a pathological condition, indicating advanced transtentorial herniation, but some degree of transtentorial herniation may be present without the occurrence of such hemorrhage as indicated by guest on October 14, 2017 http://stroke.ahajournals.org/ Downloaded from
cated by our own cases with secondary occipital lobe infarction without brain stem hemorrhage.

It has been postulated that either the displacement of the brain tissue per se,\textsuperscript{2, 11-13, 15} occlusion of veins at the level of the tentorial notch,\textsuperscript{4, 15, 16} or lengthening and angulation of the penetrating arteries caused by caudal displacement of the brain stem,\textsuperscript{17, 18} are the reasons for the appearance of secondary brain stem hemorrhages. It is contended that secondary brain stem hemorrhage occurs only in the presence of active circulation in the damaged blood vessels of the displaced rostral brain stem.\textsuperscript{11}

There is some variation in the incidence of secondary brain stem hemorrhage reported by different authors. Our finding that 45\% of the patients with lethal cerebral hemorrhages had secondary brain stem hemorrhage, is comparable to 57\% reported by Cohen,\textsuperscript{6} but higher than the frequency of 14\% and 31\% reported by Poppen\textsuperscript{19} and Klintworth,\textsuperscript{19} respectively.

Most patients died within 48 hours, which may indicate that in hemorrhage it is the expanding lesion and not reactive edema which is the primary cause of secondary brain stem hemorrhage.

In cases of ruptured aneurysm a frequency of 36\% of secondary brain stem hemorrhages was found, which is a higher value than the frequency of 21\% reported by Cohen.\textsuperscript{6} Secondary brain stem hemorrhage was observed with equal frequency in early and late death in patients with ruptured aneurysm. Most patients died shortly after either the acute episode or after a rebleeding from the aneurysm.

The frequency of secondary brain stem hemorrhage in cases of infarction was 15\%, which is comparable to 9\% reported by Cohen\textsuperscript{6} and 11.6\% reported by Klintworth.\textsuperscript{19} The finding that secondary brain stem hemorrhage had the highest frequency from day 1 to 5, with the maximum at day 4, is consistent with the prevailing clinical concept\textsuperscript{19, 20} and recent CT findings\textsuperscript{22} indicating that cerebral edema becomes maximal at 2 to 7 days after infarction. Our results do not confirm results of Bounds,\textsuperscript{23} who found that in 100 cases of recent cerebral infarction 31\% of the deaths were caused by transtentorial herniation with maximum at 1 to 2 days. The neuropathology of transtentorial herniation was, however, not described in their study.

The great difference observed in the present study between cases of secondary brain stem hemorrhage in cerebral infarction with thrombosis in comparison with those without thrombosis, can only partly be explained. As the extracranial arteries were not routinely dissected we have undoubtedly missed some of the thrombosis. The time of death after the acute attack in cases with demonstrated intracranial thrombosis versus those without is broadly similar and it can hardly explain the difference.

Impaired general circulation, including circulation within the brain stem, precluding development of secondary brain stem hemorrhages in cases of infarction without thrombosis in the cerebral vessels might contribute to the difference, but in this material we have no evidence of such impairment of the general circulation.

A possible explanation might be that the acute lesion has been larger in patients with proven arterial occlusion resulting in the development of more marked edema and thus in a "larger space occupying lesion" and more pronounced transtentorial caudal herniation. Sex-related differences in the occurrence of secondary brain stem hemorrhages are a debated matter. Some authors reported higher frequency in men\textsuperscript{6, 7, 24} and one author in women.\textsuperscript{6} The present study does not demonstrate a significant difference between the two sexes. Our results indicate paucity of secondary brain stem hemorrhage in very young persons, a finding which is in agreement with earlier investigations\textsuperscript{6, 7, 23}

The diminished frequency of secondary brain stem hemorrhages in young persons may be caused by a higher elasticity of the tissues. The tendency towards slightly decreased frequency of secondary brain stem hemorrhage in the very elderly (not significant) may be caused by cerebral tissue atrophy resulting in increased extracerebral space.

Occipital lobe infarction is a well defined pathological entity,\textsuperscript{25, 26} secondary to increased supratentorial pressure. The condition results from a displacement of the posterior cerebral artery and the hippocampal gyrus through the tentorial notch following stretching and compression of the cortical branches of that artery against the tentorial edge.\textsuperscript{24} The observed frequency (3.5\%) of such cases is surprisingly high and has not been reported previously. No correlation was found between occipital lobe infarction and secondary brain stem hemorrhage. The main finding of the present study was that secondary brain stem hemorrhages were frequent in all three groups investigated. They are strongly correlated to transtentorial herniation and indicate major disturbances of the brain stem. It can be assumed that they have contributed significantly to the death of the patients. The present material does not allow to draw conclusions on differences in the cause of death among patients with and without secondary brain stem hemorrhage.

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Hypertensive Putaminal Hemorrhage Presenting as Pure Motor Hemiparesis

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AND J. P. MOHR, M.D.

SUMMARY A 44 year old hypertensive man presented with a pure motor hemiparesis, and CT scan showed a putaminal hemorrhage. The clinical course was characterized by rapid resolution of the deficits. This case illustrates a variety of putaminal hemorrhage of good functional and vital prognosis, and stresses the value of CT scanning as a tool for diagnosis and prognosis.

HOMIPARESIS OR HEMIPLEGIA without sensory, visual or speech deficit (Pure motor hemiparesis, PMH) is the classical presentation for lacunar infarction in the internal capsule or basis pontis. Other reported causes of this clinical syndrome include: infarcts or cortical, pyramidal, or midbrain location, metastases, multiple sclerosis, nocardial abscess, post-craniotomy hemorrhage, and hemorrhages in the basis pontis or internal capsule. PMH has not been described in the setting of primary hypertensive putaminal hemorrhage. This report documents, by detailed neurological evaluation in the acute stage, an instance of a syndrome of PMH in putaminal hemorrhage.

Case Report
A 44 year old left-handed hypertensive male noticed right arm weakness and slurred speech after awakening on 8/8/82. He had no headache, nausea, vomiting or gait difficulties. Over the following 2 to 3 hours the right arm paresis worsened and a mild weakness of the right leg developed. When examined 4 hours after the onset, he was alert, oriented, and gave an accurate description of the events leading to admission. His speech was dysarthric but free of dysphasia. The blood pressure was 220/130. Motor examination showed a moderate paresis of shoulder abduction and elbow flexion, with minimal weakness of distal movements. The lower extremity had slight paresis of foot dorsiflexion, with intact proximal strength. The deep tendon reflexes were slightly hyperactive in the right arm, and plantar reflexes were flexor. Coordination was intact bilaterally.

Sensation was intact for touch and pin-prick in limbs, trunk and face. The slightest stimulation of individual hairs on the right limbs was felt normally and symmetrically. He did not extinguish to double simultaneous tactile stimulation. Joint position and vibratory sense were intact. Stereognosis, barognosis and graphesthesia were normal and symmetric.

Cranial nerve testing showed a marked right inferior facial palsy. Otherwise the examination showed full visual fields to single and double simultaneous stimuli, normal extraocular movements without gaze preference or nystagmus, reactive pupils of 2 mm diameter, intact facial sensation, preserved palate and tongue movements, and absence of bucco-lingual dyspraxia.

CT scan on admission showed a small area of high attenuation (96 Hounsfield units) at the level of the left
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