given in the preceding table were taken on capillary blood. Those described as "after plasma" were taken five to fifteen minutes after the transfusion was completed. The mean-corpuscular-volume estimations were made at the same time but on venous blood. Each of the cases was given 500 c.cm. of plasma saline, twenty-five to thirty-five minutes being taken over the transfusion.

The following patient (Case 16) was given one litre of plasma, and made the most dramatic response I have yet seen. I first saw her at the end of operation, when a cerebellar tumour the size of a tangerine had been removed. She had lost a large amount of blood and was in a very bad condition—very pale and with no palpable pulse. After 600 c.cm. had been given in thirty minutes her colour had improved and her pulse had not only returned but registered a systolic pressure of 98 mm.

Case 16 Post-operative	(2.30 ... 3,150,000)	600 c.cm. plasma from 2.30 to 3.0 400 c.cm. plasma from 3.0 to 4.0
	(2.55 ... 3,415,000)	
	(3.15 ... 3,620,000)	
	(3.45 ... 3,395,000)	
	(5.00 ... 4,175,000)	

Discussion

It will be seen that in each of these cases the transfusion of plasma was followed by a rise in the red cell count. Mathematically, of course, the addition to the circulation of 500 c.cm. fluid might be expected to reduce the cell count by upwards of 10 per cent. This rise in cell count must have been due to the return to the circulation of some or all of the side-tracked stationary corpuscles.

It will also be seen that in those cases in which it was measured the mean corpuscular volume was found to return towards normal after the transfusion. This fall in mean corpuscular volume is probably very important. One can imagine that the rapid addition to the circulation of 500 c.cm. plasma would mechanically cause a rise in blood pressure and wash back into the circulation many of the missing corpuscles. By using Barger's capillary-tube technique I have found that the osmotic pressure of the transfused plasma is higher than that of the recipient's. This is due partly to the fall in osmotic pressure of plasma which takes place as a result of haemorrhage, and partly to a rise in the osmotic pressure of the stored plasma before it is removed from the corpuscles. The latter is probably due to the rise in the potassium content shown by Downman, Oliver, and Young (1940) and by Aylwood, Mainwaring, and Wilkinson (1940). The osmotic pressure of the patient's plasma is raised by the transfusion of fluid of higher osmotic pressure, and therefore fluid now passes out of the red cells again and their mean corpuscular volume is reduced. This may well be the turning-point in clinical improvement, as it breaks the vicious circle formed by low blood pressure, dilution, and swollen corpuscles. The smaller cells, the greater oxygen capacity of the blood, and the raised blood pressure enable the body thenceforward to keep the corpuscles in circulation.

Though this series of cases is small its consistency provides strong evidence of the value of this method of treatment, and the previous investigations supply a rational explanation for its success. If the results obtained are confirmed on a larger series of cases it is likely that in the near future, especially in military surgery, transfusion with plasma will become a routine measure in the treatment of haemorrhage. A possibility which should not be ignored is that equally good results might be obtained from some artificial solution.

Meanwhile, in many parts of this country banked blood has fallen into disrepute. It is urged that transfusion

centres should again take blood from all available donors and that on about the eighth day after collection the plasma should be filtered, pooled, and stored in as great quantities as possible.

Summary and Conclusions

1. Investigations, to be reported elsewhere, have shown that after haemorrhage the individual red blood corpuscles swell very appreciably in size and that large numbers of them become side-tracked out of the circulation in muscle capillaries.

2. These observations suggested a new form of auto-transfusion for haemorrhage, aimed at restoring these corpuscles to the circulation.

3. Evidence is produced that this can be effected by plasma transfusions, which should therefore rival whole-blood transfusions in the treatment of acute haemorrhage.

4. It is suggested that plasma transfusions should become a routine measure in the treatment of severe haemorrhage.

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DELAYED TRAUMATIC INTRACEREBRAL HAEMORRHAGE

BY

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The report of a single case is of questionable value, especially when, as in the following instance, the diagnosis is unproved. Some justification, however, may be found for these notes in the discussion of a clinical problem which is rarely encountered and is perhaps not so simple as at first sight it appears.

A Recent Case

Sergeant A., aged 42, was thrown from his motor-cycle on December 22, 1939, at 9 a.m. He has no memory of the accident, but remembers being within a mile of the place where it occurred, and that the roads were slippery with ice. His next memory is of coming to his senses six hours later in a civil hospital, to which he had been taken by ambulance. He had abrasions and contusions on the right forehead and nose. A cut in the forehead was stitched, his head was radiographed, and his wife was permitted to take him home by car, a distance of twelve miles. He remained in bed at home for a week. During this period he had no headache or other symptoms. His convalescence was uneventful, and he returned to duty on January 22, 1940. On January 28 he slipped while walking on ice, and fell, sustaining a cut at the base of the nose. He was dazed for half an hour afterwards.

At 7.30 a.m. on March 2, having been on duty during the previous night, he was sitting at a table when he was seized

with a very sudden and acute pain in the top of his head. He thought he would go mad with the headache, and went upstairs to the sick orderly's room to get relief. He lay down there, and an hour or two later was taken to hospital, still in severe pain. From this time onwards his memory is confused. It appears that he was suspected of having cerebrospinal meningitis. He was transferred to a Royal Air Force Hospital on March 3, when he was examined by Squadron Leader Denis Brinton. He was then found to be confused and disoriented. The only abnormalities noted on examination of the nervous system were slight incoordination in movements of the left lower limb, left knee- and ankle-jerks brisker than those of the right, and a left extensor plantar response. The blood pressure was 120/60, and the arteries were normal. Lumbar puncture gave a xanthochromic fluid, under no positive pressure, containing 900 red cells per c.mm. and 80 mg. of protein per 100 c.cm. The Wassermann reaction in blood and spinal fluid was negative. On March 4 the dura mater was examined by Wing Commander Cade through three burr-holes, one in each frontal region and one in the posterior right parietal region. The dura appeared normal and under normal tension, and was not opened. I saw the patient for the first time on March 6. He was alert, but still confused and disoriented, with an extensor plantar response on the left. A day or two later his mental state began to improve.

He was admitted to a military hospital for head injuries on March 21. He was then mentally alert, clear, and correctly oriented. His memory, especially for recent events, was poor. He showed a slight right enophthalmos, and the right pupil was somewhat smaller than the left. No other abnormality was noted except a slight weakness of flexion at the left hip, the left knee- and ankle-jerks slightly brisker than those of the right, and a left, extensor plantar response. The family history contained no record of migraine or strokes. He himself had had no previous illness or accident.

There can be no doubt that this patient sustained a cerebral injury of some severity (traumatic amnesia of six hours), from which, however, he made a rapid and apparently complete recovery. There can be little doubt either that ten weeks later there occurred a haemorrhage with damage to the brain and leakage of blood into the subarachnoid space. The physical signs suggested a lesion of the right frontal lobe, and it was in the right frontal region that he had been injured. The question at issue is whether the haemorrhage was of traumatic origin.

Bollinger's Cases and His Conclusions

The occurrence of delayed intracerebral haemorrhage has been accepted as a rare sequel of head injury since Bollinger's paper in 1891. He suggested that as an immediate effect of what appeared to be a minor head injury there might be small areas of softening, and that in these the wall of an artery might sometimes be involved, with eventual necrosis and rupture of the wall. The interval between injury and haemorrhage might be from a few days to three or four weeks. These conclusions were based upon post-mortem observations in five cases. One was that of a woman aged 70. The clinical details in this case are meagre. She died a short while after a head injury, and a haemorrhage was found in the wall of the fourth ventricle. This record is not of much value. The others deserve scrutiny.

A man aged 26 was struck by a poleaxe. On the twentieth day after this he developed severe headache: six days later he had a sudden hemiplegia, and died on the thirty-second day after the injury. At the necropsy a fracture of the inner table at the site of the injury was found, with haemorrhage in the meninges and in the fourth ventricle.

A woman aged 39 sustained a bruise on the forehead and had headache next day. On the twelfth day after the injury she had a seizure and died in two hours. The necropsy

finding was dilatation of the Sylvian aqueduct and clot in the fourth ventricle.

A girl aged 13 died suddenly and was found to have a large haemorrhage in the posterior part of the right hemisphere that had ruptured into the lateral ventricle. It was later ascertained that she had had a fall when skating three weeks previously.

A boy aged 7 fell downstairs but did not lose his senses. Three days later he became restless and gradually developed right hemiplegia and aphasia. He died on the fifty-second day after the injury. A haemorrhagic focus was found extending from the wall of the fourth ventricle on the left side through the pons into the wall of the 4th ventricle.

Now, the first of these four cases, though the injury was a severe one, is not very convincing as an example of delayed intracerebral haemorrhage. The meningeal haemorrhage may have been the cause both of death and of the blood in the fourth ventricle. In the other three cases the injury was so slight that one may reasonably consider alternative pathologies. When Bollinger recorded his observations it was not yet recognized that rupture of a congenital aneurysm in a young person is a not uncommon cause of intracerebral haemorrhage and that another rarer but not so very uncommon event is haemorrhage into an angioma of the telangiectasis variety situated in the pons or medulla. We may therefore accept Bollinger's observations so far as they go, but may question the validity of his conclusions. Nevertheless it is upon his paper that the occurrence of delayed traumatic apoplexy has been generally accepted. It was supported by the observations of Duret (1920) that in fatal cases of head injury in man, and in animals subjected to experimental injury, small haemorrhages and areas of softening in the walls of the 3rd and 4th ventricle are commonly found. Hence, it was argued, the frequency of delayed haemorrhage in these situations.

Cases in the Literature

During the subsequent fifty years occasional cases have been reported in the German literature (Langerhans, 1903; Tietze, 1926; Rosenhagen, 1930). In some instances the post-mortem investigation has been incomplete and the clinical data lacking in precision. There is, however, a considerable body of evidence to support Bollinger's original hypothesis that, following head injury, after a latent interval, usually of one to three weeks, intracerebral haemorrhage may occur. This may be situated in one or other hemisphere, with corresponding symptoms and signs; but often the clinical story is that of rapid death without definite localizing signs, and it is found post mortem that there has been haemorrhage into some part of the ventricular system.

A case recorded by Rosenhagen is one of the most convincing examples of massive intracerebral haemorrhage.

A healthy man aged 27 fell from a moving train into a tunnel and sustained slight injuries to forehead, vertex, and face. He did not lose consciousness, but was confused. He left hospital at the end of eighteen days with his injuries healed but suffering from headache. Five weeks after the accident he returned to work against medical advice. Three weeks later he woke in the night with severe headache and found his left limbs weak. He was admitted to hospital comatose, with a left hemiplegia. The cerebrospinal fluid contained no blood. He died eight hours later. At the necropsy a recent haemorrhage the size of an apple was found in the white matter of the right fronto-parietal region. This had leaked slightly into the anterior horn of the ventricle. Neither macroscopic nor microscopical examination revealed the source of the haemorrhage. In particular, no aneurysm could be discovered.

Less attention seems to have been given to the subject of delayed traumatic apoplexy in the English and French literature.

Ritchie Russell (1932) quotes as a clinical example a youth aged 17 who was found unconscious on the road beside his bicycle. He recovered consciousness after an interval of several hours, and thereafter showed the clinical picture of subarachnoid haemorrhage, which was confirmed by lumbar puncture. He was discharged from hospital after a fortnight, relieved of symptoms. A month later he was readmitted on account of a rapid onset of severe headache and of drowsiness. Deeply blood-stained fluid was obtained by lumbar puncture, and he subsequently made an uninterrupted recovery.

The diagnosis in this case seems open to doubt. It is arguable that the patient had a congenital aneurysm and that from this a subarachnoid haemorrhage occurred, causing him to lose consciousness and fall off his bicycle. Later, as often in such cases, there was a recurrence of haemorrhage with ultimate recovery.

Differential Diagnosis between Aneurysm and Head Injury

The differential diagnosis between aneurysm and head injury as the cause of a sudden cerebral catastrophe may be far from easy, as is shown by the following case.

A healthy man aged 22 was found on the road in a dazed condition on May 5, 1935. His car, which he had been driving alone, was overturned. He was badly bruised about the face and eyes. When examined by his doctor three hours later he was still dazed and could give no account of what had occurred. During the next few days he was restless and confused, vomited frequently, and complained of severe headache. He gradually improved, but on May 15 suddenly became unconscious. It was noted that his head was retracted and that Kernig's sign was present. On the following day a lumbar puncture was done, revealing a heavily blood-stained fluid. He gradually improved, but was restless and confused for several days. On May 17 his temperature, which had been subnormal since the 15th, gradually rose, reached 101° on the 18th, and gradually fell to normal on the 24th. On the 29th, while being given an enema, he suddenly became unconscious. He rapidly recovered, but again was restless and confused, with severe headache and vomiting.

The cerebral symptoms at the onset had not unnaturally been attributed to head injury, and it was assumed that the "attacks" on May 15 and May 29 had been due to delayed meningeal haemorrhage. I saw the patient on May 30 and found him restless and confused, complaining of severe headache, with a stiff neck and a positive Kernig sign, but with no signs of any local cerebral damage. He was able with a little persuasion to answer a few questions, and I elicited from him the following facts. On May 3, two days before the accident, he had had a sudden pain in the back of the neck. It passed off and he made light of it. Questioned about the accident, he remembered that while driving his car something happened in his head and everything went blank. His next memory was of lying in the road with his car overturned. This was conclusive evidence of an attack of unconsciousness causing the accident, and suggested strongly that the cerebral symptoms observed after the accident were sequelae of this attack. If they had been of traumatic origin he should have had a retrograde amnesia blotting out the memory of symptoms immediately preceding the accident. Hence it appeared extremely probable that the whole clinical story was that of a ruptured congenital aneurysm, which incidentally had caused him to lose control of and overturn his car.

After I saw him he rallied, but on June 4 he again suddenly became unconscious, and died in a few minutes. I was able to obtain the brain, which showed the characteristic picture of extensive subarachnoid haemorrhage. Careful dissection

revealed a ruptured aneurysm at the junction of the left anterior cerebral and anterior communicating arteries.

A second case, briefly recorded by Ritchie Russell (1938-9) is a more convincing example of delayed intracerebral haemorrhage.

A man aged 21, following a head injury with fractured skull, suffered from headache and mental confusion for two or three days, but was out of bed on the tenth day. On the twelfth day he suddenly developed aphasia and right hemiplegia. The cerebrospinal fluid in this case was brown in colour but without increase of cells or protein. The patient made a satisfactory recovery.

Dubois's Views and Cases

Dubois (1936), reviewing the subject of delayed post-traumatic apoplexy, has expressed the opinion that the occurrence is so exceedingly rare that its existence may perhaps be doubted. He found eight possible examples among 1,700,000 cases of accidental injury collected by the Caisse Nationale Suisse. In four of these patients cerebral arteriosclerosis was known to exist before the injury, which in no case was severe. The latent interval was from twelve hours to four days. He considers that although from a medico-legal standpoint the possibility of a traumatic factor in these cases cannot be denied, it is unproved.

Two other cases briefly reported are more convincing. Both patients were between 30 and 40 years of age and in good health before the accidents. Both suffered severe head injury, with headache, vertigo, and mental symptoms persisting up to the date of the subsequent ictus. This in both instances took the form of a sudden hemiplegia, occurring in one case on the twenty-first and in the other on the twenty-fifth day after the injury. In neither case was the hemiplegia progressive or fatal.

Dubois's other two cases are examples not of delayed traumatic apoplexy as described by Bollinger, in which the haemorrhage occurs a few days or weeks after the injury, but of a sequence which is different in time relation and pathology. In these two cases the symptoms of cerebral haemorrhage followed severe cranio-cerebral injury after intervals of fourteen and sixteen years. In the latter case no necropsy was obtained. In the former a cyst was found in the left temporal lobe communicating with the lateral ventricle, and the ventricles contained blood. The sequence presumably was as follows: As an immediate effect of the original injury a circumscribed intracerebral haemorrhage occurred. The blood being absorbed, a cyst remained, and the final ictus was due to rupture of a vessel in the wall of the cyst. In this instance the rupture may well have been due to vascular degeneration, for the patient, aged 51 at the time of death, is said to have shown early arteriosclerosis.

Chronic Intracerebral Haematoma

In the following case the sequence was probably of the same order, but the delayed haemorrhage was apparently caused by further trauma. This case is also of interest in that it provides an example of chronic intracerebral haematoma causing symptoms of increased intracranial pressure.

A married woman aged 26 came under my care at Guy's Hospital on January 26, 1937, with the leading complaint of severe headaches following a minor head injury in October, 1936. There was a record in her past history of two severe head injuries. At the age of 10 she was struck on the right temple by a cricket ball while playing in a park. She was unconscious for an hour and was then taken home. She

vomited repeatedly during the night and developed a severe headache. Next day she was admitted to hospital. Her memory of the next two weeks was vague, in contrast to her clear recollection of the hours immediately following the return of consciousness after the injury. She recovered completely, and was back at school three months after the accident. At the age of 19 she fell down a flight of stone stairs and struck the back of her head violently. She immediately became unconscious, with amnesia for the next eight or nine hours. She was admitted to Guy's Hospital, where she remained for six weeks. During the first fortnight she complained of headache but had no other symptoms. At the end of October, 1936, she was standing on a chair when a fire-work went off in the room. She fell, striking the back of her head on the corner of a light table. This occurred at 4 p.m. She was dazed for an hour and subsequently felt sick and dizzy. On going to bed at 10.30 p.m. she developed severe headache, which kept her awake. She dropped off to sleep in the early hours of the morning and woke at 10 a.m. to find her left arm and leg tingling and powerless. She was admitted to Lambeth Hospital, where she was found to have a left hemiplegia. The notes record headache, drowsiness, and vomiting as additional symptoms. At the end of six weeks she had recovered most of the power in her left arm and leg, but still complained of severe headache and occasional vomiting.

On admission to Guy's Hospital she showed bilateral papilloedema and weakness of the left limbs, with an occasional extensor plantar response on the left. The visual fields were full and there was no defect of sensation. Radiographs of the skull revealed no abnormality. The cerebrospinal fluid was under a pressure of 300 mm., but showed no abnormal constituents. After the lumbar puncture she had two brief attacks of unconsciousness, with twitching of the left arm and leg.

She was transferred to the National Hospital, where operation was performed on March 10 by Mr. Julian Taylor. The right fronto-parietal cortex was exposed by an osteoplastic flap, and it was observed that the convolutions behind the Rolandic fissure were bulging. A needle inserted at this spot entered a cyst, from which a quantity of brownish-yellow fluid was withdrawn. A portion of the cyst wall was excised for microscopical examination, and was reported by Dr. Greenfield to show no evidence of new growth. The patient made an uninterrupted recovery and has since remained well.

Looking back on the history of this case I am inclined to think that an intracerebral haemorrhage must have been caused by the blow from the cricket ball at the age of 10. The story of a lucid interval on this occasion is suggestive. If so, presumably the second injury at the age of 19 caused further haemorrhage into a small cyst remaining from the first injury. The third injury caused further and more extensive leakage, with the consequent formation of a cyst whose contents remained fluid and increased in volume, presumably by osmosis from the cerebrospinal fluid, as happens in chronic subdural haematoma.

That an encysted intracerebral haemorrhage from whatever cause may in this way come to present the symptoms of an expanding lesion has been recognized from the publication of occasional cases, and is illustrated by case reports in a paper by Craig and Adson (1936). Four of their cases showed papilloedema in addition to the signs of a localized cerebral lesion. In one of these cases the haemorrhage was probably of traumatic origin.

The patient, a healthy man aged 39, gave the history of a fall, with injury to the head, transient disturbance of consciousness, and general weakness for four days. Three months later, without apparent cause, he suddenly developed a right hemiparesis and subsequently progressive weakness and dysphasia together with headache and papilloedema. At operation viscous and laminated clot was evacuated from a subcortical cyst, and the patient recovered.

In another of their cases, without papilloedema, the story was that of an expanding lesion.

A man aged 62, with normal arteries and a blood pressure of 116/68, gave a history of severe intermittent headache following a motor accident twelve years previously, with a fractured nose. During the three months before admission he had had more severe headache, and gradually developed left-sided weakness and a left homonymous hemianopia. A right parietal exposure showed flattened convolutions, and a cyst was encountered at a depth of 4.5 cm., from which 75 c.cm. of dark yellowish-brown fluid was aspirated. Tissue from the cyst wall revealed no evidence of neoplasm, and following the operation there was improvement.

Commentary

If we now return to the question propounded in the case from which this discussion started it appears to be one which cannot be given an unqualified answer. The symptoms which supervened ten weeks after the injury were such that if there had been no such injury diagnostic honour would have been satisfied with the assumption that they were due to leakage from a congenital aneurysm. Such an occurrence we know to be common in otherwise healthy persons of middle age. So also is the occurrence of head injury. By contrast it appears that delayed traumatic apoplexy is extremely rare—so rare that if this possibility is weighed against that of coincidence of head injury and aneurysm the balance is undecided.

Fortunately for ourselves, the accident in this case did not occur on duty and was not caused by the fault of anyone other than the patient, so that there were no medico-legal implications. If there had been there can hardly be any question that the man must have received the benefit of the doubt. An arterial radiograph after thorotrast might have been enlightening, but this measure was not deemed advisable. Even if it had been negative the diagnosis would still have been in doubt, for it is not every aneurysm that is revealed by this means.

Summary of Conclusions

There are two varieties of delayed traumatic apoplexy—early and late. Both are of extremely rare occurrence. In the early variety the haemorrhage occurs within a few weeks of the injury, probably as the result of traumatic weakening of an arterial wall. Blood is often found in the ventricles and cerebrospinal fluid. The clinical picture may very closely resemble that of a ruptured congenital aneurysm. In the late variety the interval between injury and apoplexy may be several months or years. The mechanism is haemorrhage into a cyst resulting from intracerebral haemorrhage at the time of the injury. The clinical symptoms are usually those of a cerebral haemorrhage.

Delayed symptoms may result from an intracerebral haemorrhage, dating from the time of the injury, as the result of cyst formation with progressive increase in volume—chronic intracerebral haematoma. The symptoms then resemble those of a cerebral tumour.

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