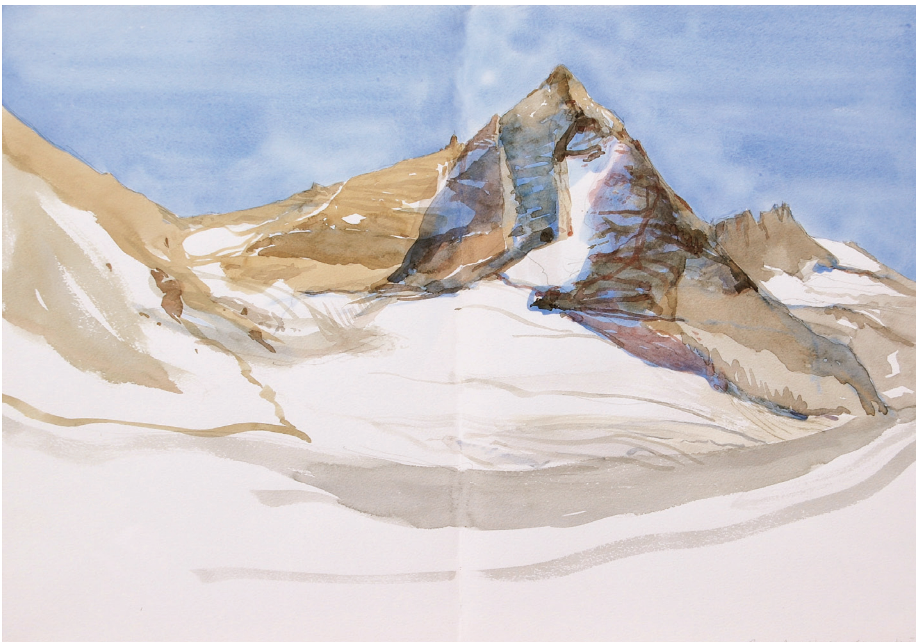
Science



156. Simon Pierse, *Beca di Monciair from Rifugio Vittorio Emanuele II*, 2006, watercolour, 42 x 59cm

BRIAN CUMMINS

Measuring Intracranial Pressure in The Himalaya

A 20-year old paper by Brian Cummins introduced by Jim Milledge

In September 1992, when revising our textbook, High Altitude Medicine and Physiology (Ward, Milledge & West) for its second edition, I heard about an extraordinary study carried out by Brian Cummins, a neuro-surgeon working in Bristol. I got in touch with him and briefly discussed the study and the 1985 expedition to Hagshu peak (6330m) in Garhwal (below) on which it was done. He faxed me an article he had written about it but never published. From this I extracted the salient results and mentioned them in the relevant chapter of our textbook as a 'personal communication'. He never published the article or any other about the study except for an abstract presented at a conference of the 8th European Congress of Neurosurgery. Brian retired from the NHS and died in 2003.[1]

I have also briefly discussed the expedition with its leader, Mike Rosser, an AC member, and he believes the article was intended for the AJ. The fax which Brian sent to me is now fading so I made a transcript of it before it was lost forever. I thought that AJ readers should have a chance of learning about this bold piece of high altitude medical research. It has not and never will be repeated, since nowadays ethical committees would not allow such a study. His style, as you can see from the very first paragraph below, is also charmingly free of pomposity and jargon. ***JM***

When you ask a middle-aged neurosurgeon, lazing fatly on a Gower beach watching the more energetic members of the Mountain Rescue team shin up three cliffs or fall off windsurfers, if he wants to come to India next year as medical officer of a HIMALAYAN EXPEDITION, the only answer you deserve is 'yes'. Romance courses through tortuous arteries as briskly as in the elastic days of youth. The trouble is, the silly beggar may want to 'do something', in order to justify his existence. In our case, it was holes in the head.

The purpose of the investigation was serious enough, even if its execution had its light-hearted moments. Acute mountain sickness (AMS) has been the complaint of high altitude travellers since the Spaniards colonized the Andes, and a Jesuit priest thought of casting up his soul in the thin air. Ravenhill noted in 1913 that PUNA (one of the South American terms for AMS) caused headache, unwellness, fatigue and vomiting, which usually settled down but could sometimes cause death, in coma or from acute congestion of the lungs. It was apparent to the early mountaineers that being young and fit did not protect you. Whymper on Chimborazo at 16,664ft

157.
Hagshu Peak (6330m) in the Garhwal Himalaya, the objective of the 1985 expedition led by Mike Rosser.

suffered badly with the two Carrels, while 'strange to relate Mr Perring did not seem to be affected at all'. Mr Perring was 'a rather debilitated man and distinctly less robust than ourselves. He could scarcely walk on the flat road without desiring to sit down.' The despised individual looked after the heroes until they were better.

In 1985, Ross, in the *Lancet* [1985 I p990-1], postulated that the reason that the young and fit were frequently stricken by AMS was the tight fit of their brains into their skulls. The brain is moored in its own cerebrospinal fluid snugly within the skull and has cavities inside (the cerebral ventricles) which act as reservoirs. These ventricles may be of different sizes in individuals, commonly being smaller in the young. The only way out is through a hole at the bottom of the skull, the foramen magnum. If the brain swells, the cerebrospinal fluid is squeezed out until there is no more left and then the pressure in the skull (intracranial pressure, ICP) rises. If it rises close to the arterial pressure, no blood flows through the brain and you die, in coma.

The brain may swell at high altitude because it lacks oxygen. This causes the cells to swell (cerebral oedema) and the cerebral blood vessel to expand in an attempt to increase flow of blood, simply adding to the volume packed into the constricted space of the skull.

In general the younger you are, the tighter the brain fits into the skull; the older you are, the more the brain has lost its cells, the bigger the ventricles and the more CSF there is to bathe it. Individuals vary widely and it is impossible by simple clinical examination to decide the volume of CSF available.

The computerized axial tomographic scan (CT scan) can tell the snugness of fit of the brain to any individual's skull. I felt that this technique might be a way of studying susceptibility to AMS.

Method of investigation

Each of our party had a CT scan before setting off. This was reported by a consultant radiologist and the films put into the safe keeping of Dr Charles Clarke. In ignorance of the results of the CT scans, Margaret Coldsborough, an experienced nurse, conducted a daily interview and symptoms were scored for each member of the expedition. When Margaret left with the trekking party, I conducted the interview, often in retrospect when the climbers came down to advanced base camp at 15,500ft. This interview was structured into the symptoms Fletcher and colleagues suggested in 1985 *Quarterly Journal of Medicine*, 93-100, and accompanied by self-assessment forms scoring the same complaints.

Thus, each day, each climber had to fill in and to confess to whether he was unwell, fatigued, lacked appetite, had headache, was unsteady, and had either irregular or difficulty in breathing. The score was rated 0-3 for each symptom, 0 being 'no problem', 1 'not troubled', 2 'Makes life miserable' and 3 'stops you doing what you want to do'.

This method proved effective, the interview and self-assessments matching well.

Measurement of intracranial pressure (ICP)

Early in 1985 a telemetric button to measure the pressure within the skull became available. This meant that a battery-operated sensor could detect the ICP by a radio signal generated in a coil within the skull. All that was needed was a little hole in the skull, so that the button could rest on the membrane lining it. The pressure could then be measured in any position of the head.

I had already been worried about Duncan, since he had had a head injury that required a shunt to siphon CSF away from the brain. I thought he might have problems at altitude if there was no CSF reserve. Consequently I suggested this technique as a safety device and since I was interested in the physiology, I wanted one too. Mike Rosser, the leader, a completely 'normal' man volunteered himself. In the event, Duncan's monitor proved very useful.

The operation was very simple. I had mine put in the week before the others to make sure it was innocuous. My senior colleague, Huw Griffith, at my behest, drilled the hole, placed the button under local anaesthetic. I was surprised how noisy and how completely painless it was. An hour after

158. Brian Cummins measuring the intracranial pressure measured on a fellow expedition member in the field.

the insertion of the button I was conducting my routine outpatients session. British patients being what they are, none raised an eyebrow at the shaven head and fresh dressing applied to their doctor.

The other two monitors I put in myself. Anxious enquiry by phone the following day revealed that one patient was teaching gymnastics while the other was halfway up a cliff.

At the turn of the century, Alberto [Angelo] Mosso in his *Life in The High Alps* lamented, 'It was my wish to find some one with a hole in his skull who would have been willing to come with me on the Monte Rosa expedition but I was not successful in my search.' We had three.

The general health of the expedition was good once the polluted waters of the lowland had been left behind. The trekkers took home with them one unfortunate climber who had drunk not wisely but too well, and who had contracted very severe fever with diarrhoea which responded just in time to massive doses of metronidazole. Above base camp at 12,000ft we contended with little except altitude and lack of good food. One climber suffered very severely from prolapsed piles brought about by diarrhoea, which played havoc with his otherwise imperturbable self-assessment and interview scores. His stoicism was bent a little by my digital replacement of the fallen parts, reminiscent in fact of the poor King Edward being put to death in Berkeley Castle, whose cries could be heard across the Severn. Within three days he was back on his feet and climbing with the best.

Complaint scoring related to CT scan

Our scoring system began with our walk in from Golhar at 5,900ft. There were few symptoms referable to altitude until we reached base camp at 12,000ft, by which time the trekking party had left. At base camp, the party of 11 consisted of seven climbers, three base camp supporters and the Indian Liaison Officer, who had not had a scan. Baggage to base camp was by mule, and after by backpack, the doctor and his 16-year old son earning their keep by portering while the only woman, Jo, became an expert chapatti maker as well as carrying as heavy loads uphill as the rest. There were days when the party was split, and the three supporters reached no higher than 16,500ft where the highest ICP measurements were made on a glacier. Each individual filled in his complaints scores daily, and the interview scores were completed as soon as possible.

It soon became apparent that one climber was affected by altitude far more than the rest, and at low altitudes. He had had problems on a previous expedition to the Himalaya, and now suffered badly with each gain in height, so that in the end I gave him Diamox, which eased his discomfort considerably. Two others were severely affected by the combination of rapid height gain and load carrying, which did not affect the rest so adversely, although no one was entirely without symptoms.

On return, it was possible to sum the complaints score for four weeks and to compare the results with the radiologist's report of the brain scan [Table 1].

These results support the postulate of Ross, that the tightness of fit of the brain into the skull is an individual phenomenon and determines the susceptibility of the individual to acute mountain sickness.

Table 1.
Results of CT scans, size of cerebral ventricles, and AMS scores.

*Base camp supporters – not above 16,500ft.

**Results weighted by 3 days severe diarrhoea and pile prolapse.

Subject	Age Years	AMS Score Total	Headache Unsteady Score	Cerebral ventricles Size
I.M.	29	99	20	very small
S.C.*	16	49	19	very small
D.M.	28	48	10	small shunt
A.S.	35	**36	0	large normal
M.R.	31	24	5	normal
J.J.	28	25	1	normal
B.C.*	52	16	3	large normal
S.T.	28	15	3	normal
S.R.	21	13	1	normal
J.C.*	28	10	3	normal

Measuring the ICP

After conference with expert colleagues, I decided that the intracranial pressure should be recorded at rest and in the standardized conditions of increasing stress to the system, at each session. Daily, from the beginning of the walk in to the end of the climb, as well as in Delhi and Bristol, ICP was recorded in the three subjects, except when they had climbed higher than I could take the recording instrument.

1.	Lying horizontal	i)	head straight
		ii)	head turned to right
		iii)	head turned to left
2.	Body tilted	i)	up 30 degrees
		ii)	down 30 degrees
3.	Lying horizontal	i)	breath held 40 seconds
		ii)	over breathing 30 seconds
4.	Sustained press-up 30 seconds, with breath held terminal 15 seconds.		

The pulse rate was recorded at the beginning and end of each session by digital pulse meter. Although this was easy enough at sea level (in Delhi we had done it with handstands) above 12,000ft breath holding for 40 seconds began a test of will, while the press-up was less stressful. Finding 30-degree slopes was no problem, although anchoring the subject to the rock or ice occasionally produced hilarious tangles of man and machine.

We took 776 separate recordings of the ICP, in varying climate and at altitudes up to 16,500 ft. The physiological stresses caused the expected rise and fall in pressures.

At sea level, we were all well within normal limits. Resting level of ICP in mmHg.

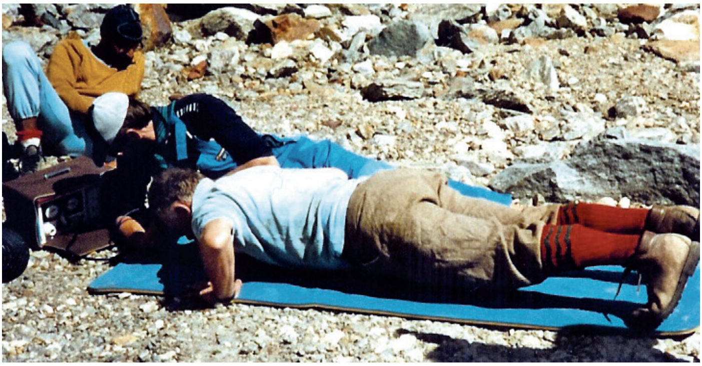
Altitude	<15,500 ft	> 15,000ft
M.R.	9.5 +- 3	14.0 +- 2.5
D.M.	9.0 +- 4	9.0 +- 3
B.C.	7.0 +- 3	6.5 +- 3

Table 2 Results of ICP measurements (mmHg) in the three subjects above and below 15,500ft.

At advanced base camp and above 15,500ft Mike's ICP rose to the upper limits of normal (15mmHg) and his stress tests showed more excursion of the values, but were not excessive. My own atrophic brain placidly accepted heights with no change from sea level.

Duncan however, reacted differently. It appeared that his shunt might keep the pressure stable until a certain point when possibly the ventricles were collapsed. Having climbed very hard with a heavy load, he was marooned with two others on a small ledge at 18,800ft for 36 hours. When he came down to camp at 15,500ft, he was exhausted and unsteady on his feet. His resting pressure was 14 mmHg but simply turning his head to either side raised this to 24 mmHg and the press up to 38 mmHg. His resting pulse was 104 and rose to 152 at the press-up. I did not need the ICP monitor to tell me that he was in trouble, but there is little doubt that it confirmed my judgement that he was suffering from altitude sickness compounded by the swelling in the brain. Sorrowfully, and against his protests I took him down to 12,000ft where in base camp within a day he recovered and his ICP returned to normal.

In the end, as it often does, the mountain won, but we learned a lot and I at least had the craven consolation that I had brought all my friends home alive.



159. Brian Cummins having his intracranial pressure measured while doing press-ups.

Comment by Jim Milledge

Although it is 24 years since Brian carried out this study, we still do not know for certain that the symptoms of AMS are due to raised intracranial pressure (ICP) though that seems the most likely explanation. We have no accepted, non-invasive, method of measuring ICP, although a number of indirect methods have been suggested and tried. Not surprisingly, Brian's study was short of numbers of subjects, which is why he felt he could not publish in the medical press. However, his results are in keeping with the hypothesis that oxygen lack at altitude, results in brain oedema, swelling. In people with small cerebral ventricles and therefore small volumes of cerebro-spinal fluid, this causes a rise in pressure within the skull. In those with larger ventricles, smaller brain volumes, the same degree of swelling results in less pressure rise. The rise in pressure causes the well-known symptoms of AMS: headache, nausea and vomiting.

I am grateful to Mike Rosser and Ann Cummins for permission to use their photos and to Mark Wilson for helpful suggestions and gathering the photos. A paper has been published by Mark, based on Brian's work, for the medical scientific press. Wilson, M. H. and Milledge, J.S. (2008). Neurosurgery 63*, 970-975*

1. Brian Cummins died on 16 August 2003. *British Medical Journal* obituary at **www.bmj.com/cgi/content/full/327/7422/1053-a**)