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Efficacy of Air Bags — a Pilot Study on Cadavers

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Summary. The efficacy of air bags in head-on collisions has been studied in 3 experiments with unembalmed cadavers on the impact sled. In one of the cases the impact produced no injuries; in the other injuries to the spine and the soft meninges in the region of the parasagittal bridging veins occured, and in the third, the bag which had been used once before, burst. In future experiments special attention should be given to the cervical spine and the superior cerebral veins.

Zusammenfassung. Der Effekt von Luftsäcken bei frontalen Kollisionen wurde in Experimenten mit nicht einbalsamierten Leichen untersucht. Hierzu wurde die a. a. O. beschriebene Versuchsanlage benutzt (Coermann *et al.*). Bei einem Experiment entstanden keine Verletzungen. Bei einem Versuch wurden Verletzungen der Wirbelsäule und der weichen Hirnhäute in der Umgebung der parasagittalen Brückenvenen erzeugt. Bei einem weiteren Versuch platzte der zuvor bereits einmal verwendete Luftsack. Verletzungen der Hals- und Brustwirbelsäule, Rippenbrüche und eine Zerfetzung der Gelenkkapsel des linken Sternoclaviculargelenkes resultierten. In künftigen Versuchen sollten besonders die Halswirbelsäule und die Vv. cerebri sup. beachtet werden.

Key words: Air bags, efficacy in head-on collisions — Efficacy of air bags — Injuries to the cervical spine.

Air bags have recently been proposed as a passive restraint system to prevent injuries to occupants of cars in head-on collisions. In the event of a collision the compressed air and explosive gases immediately inflate the bags and thereby ward off injuries to front-seat occupants thrown towards the steering wheel, the instrument panel and the windshield. But it must be questioned whether air bags really can offer such protection. It was therefore decided to test the efficacy of such bags in experiments with unembalmed cadavers.

Method

The technical equipment used for the experiments has been described by Coermann *et al.* The air bag aggregate (Olin, 270 l) was fitted to the instrument panel. The release nozzle pointed 15° downwards towards the occupants. The sensor was mounted on the front of the floor plate of the sledge and set at a sensitivity of 10 g. Below the instrument panel was a shock-absorbing deformable sheet of metal to "catch" the knees. An ordinary mass-produced seat (Daimler Benz) was used. As in previous experiments (Coermann *et al.*), cadavers were

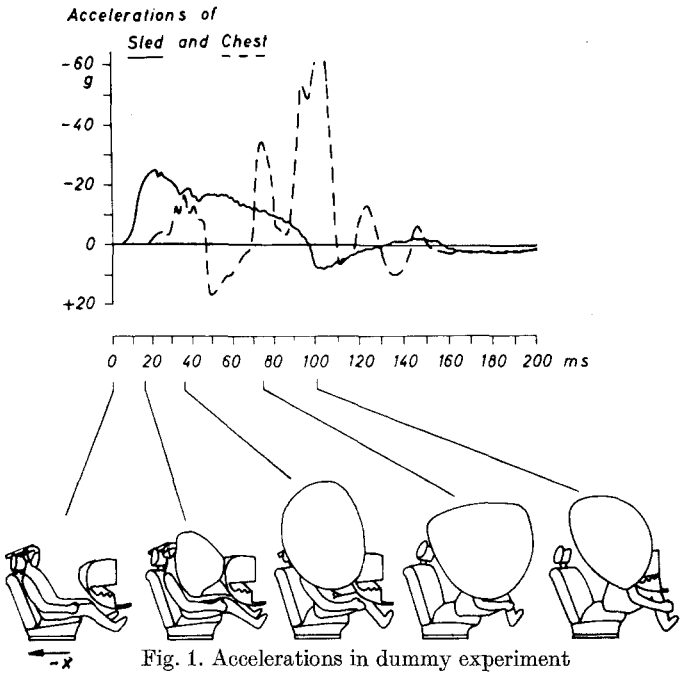

Fig. 1. Accelerations in dummy experiment

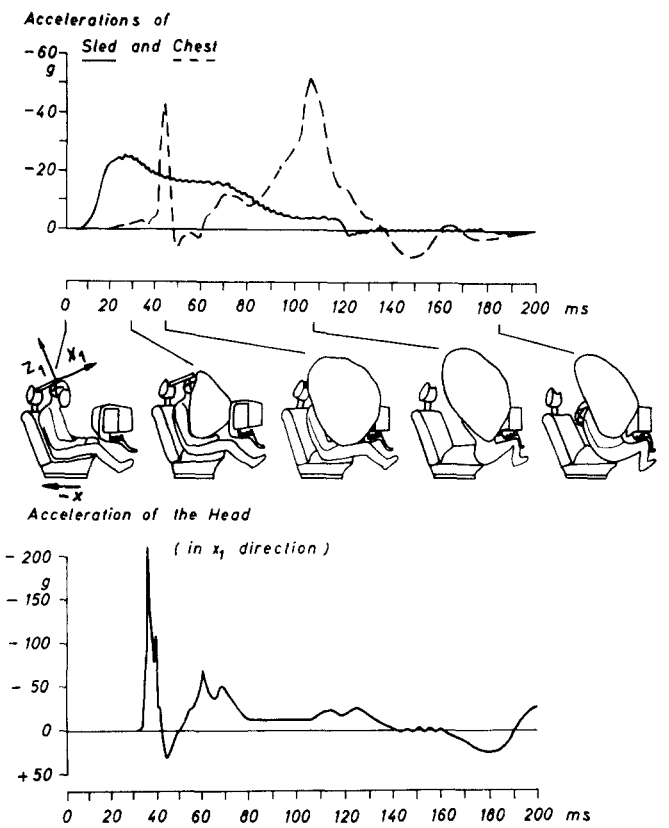

Fig. 2. Accelerations in experiment 1

used that had been kept for 3 days at a temperature of about 15°C. They showed no signs of autolysis, they were no longer rigid, and they were not embalmed.

The corpses were fitted with a helmet, whose crown was equipped with an accelerometer and a posterior plastic fin (450 mm long and 25 mm wide) to facilitate cinematographic examination of the movement of the head, when forced into the air bag.

The helmet with these accessories weighed 200 g. An accelerometer was fastened on the back of the corpse with the aid of a chest belt. The upper edge of the accelerometer was about 25 cm below the seventh cervical vertebra. The experiments were photographed with three high speed cameras, one fastened to the left side of the sledge (in direction of the impact), one was left stationary and placed to the left of the sledge and one was fixed obliquely behind the corpse for recording movements of the latter.

After the experiments the vertebral column was x-rayed and the corpses were dissected.

In order to get an idea of the movements of the body when thrown against the air-bag in a collision, one experiment was first carried out with a dummy Alderson PI 50 — AU (73 kg).

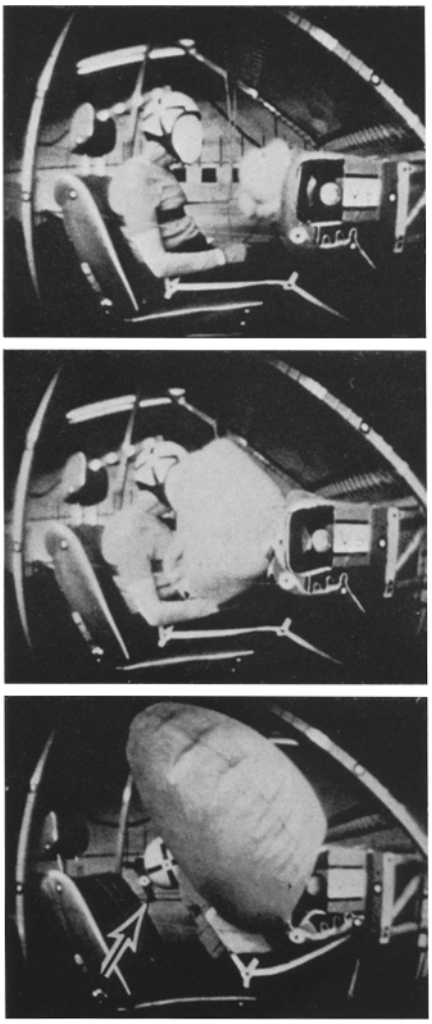

Fig. 3. Movement of the cadaver in experiment 1 (High speed film)

Results

Dummy

Air bag type Olin (270 l).

The accelerometer on the head failed at the moment of collision. At 20 msec the trunk hit the bag accelerated in the direction of the sledge ($-x$), at 45 msec the trunk was decelerated by the back of the seat ($+x$), at 70 msec it again hit the bag, and between 90 and 100 msec it collided with the instrument panel.

Experiment 1

Male aged 42, 170 cm of length. Wt 72 kp. Cause of death: Parathion poisoning.

The sequence of events was essentially the same as in the experiment with the dummy. Here, too, the acceleration of the chest was biphasic. After a brief contact with the air bag the upper part of the trunk was accelerated in the direction opposite to that of the impact ($+x$) and between 60 and 90 msec it was again accelerated, by the effect of the air bag, in the direction of the impact and at 100—120 msec it hit the instrument panel. The curve for the acceleration of the head showed a very high peak at 40 msec (the acceleration of the head preceded that of the chest). This resulted in a backward jerk of the head. This was followed

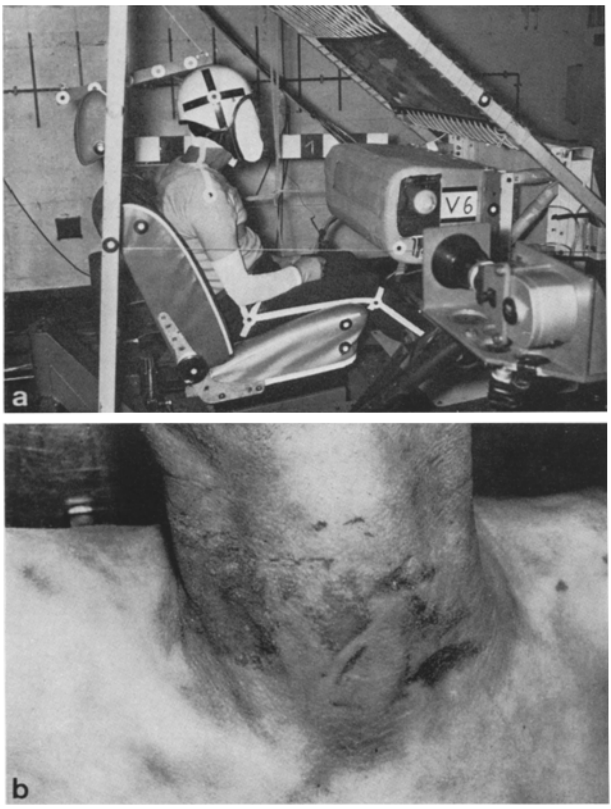

Fig. 4. Experiment 1 a: Sled ready for impact. b: Skin abrasions and ruptures on the neck

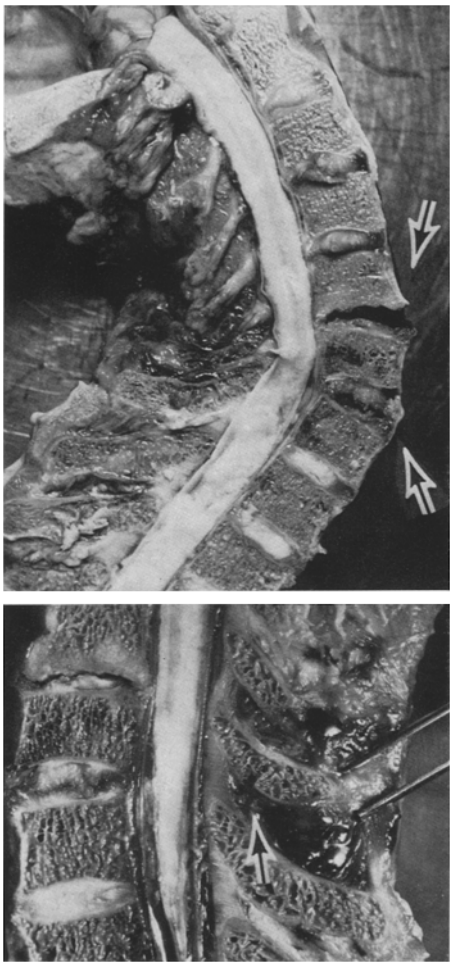

Fig. 5. Experiment 1: Cervical spine injuries

by a very short acceleration in direction opposite to the impact against the sledge. The head was afterwards thrown back (—x) at 50 msec; the trunk not before 60—65 msec. This means that the head was thrown back twice by the air bag with a considerable strain on the cervical spine.

The head never came into contact with the instrument panel, as is apparent from the films. After the collision the head was thrown to the right relative to the direction of the accelerated sledge and did not hit the back of the seat on deceleration of the vehicle. Retroflexion of the cervical spine could not have occurred because it was prevented by the frame of the sledge. The film taken with the camera obliquely from behind shows that the neck was stretched by the impact of the head against the air bag. Autopsy findings: In the anterior part of the neck was a transverse area where the skin was grazed and showed fine transverse external skin ruptures. These ruptures were probably due to overstretching of the skin.

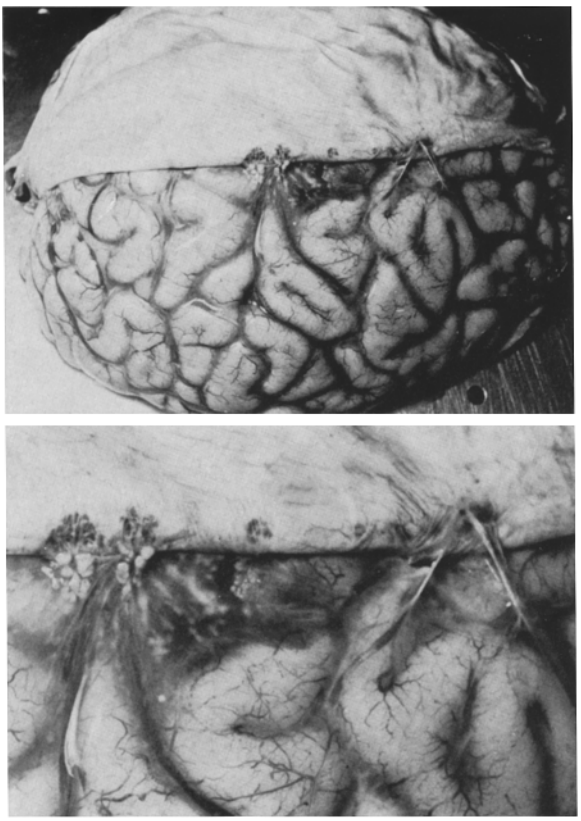

Fig. 6. Experiment 1: Parasaggital laceration of the soft cerebral meninges and subarachnoidal bleedings

Otherwise there were no external injuries. Along the borders of the longitudinal fissure of the cerebrum was a thin layer of blood between the soft meninges in the coronary area. In the environment of the bridging veins in the coronary area (superior cerebral veins) the soft cerebral meninges were lacerated. The spine was removed, frozen and sawed along its midline. The disc between the third and fourth cervical vertebra showed a rupture filled with blood. There was also a rupture of the anterior longitudinal ligament between the fifth and sixth and sixth and seventh cervical vertebrae with avulsion of a marginal bone fragment from the caudal anterior margin of the sixth cervical vertebra. The spinal process of the vertebra showed a caudal gaping fracture. The fractures were also demonstrated roentgenographicly. Haemorrhage in the environment of the spinal processes between the fifth cervical and the second thoracic vertebra. Rupture of the posterior half of the disc between twelfth thoracic and first lumbar vertebra.

No further skeletal injuries or internal injuries.

The injuries of the vertebral column and of the soft cerebral meninges were probably due to the blow against the air bag. The injury of the intervertebral disc between the twelfth thoracic and first lumbar vertebra probably occurred

at 110 msec when the lower legs were caught between the floor plate and the instrument panel and the trunk was bent backwards, as is apparent from the film.

Experiment 2

The air bag was shaped for European cars (200 l).

The bag had been used once before. The seams were checked before the experiment.

After the test one of the seams on the left side of the bag was found to have burst. Judging from the film, the corpse had been thrown through the bag against the instrument panel.

A woman aged 71, 173 cm, 95 kg. Cause of death: Myocardial infarction.

The recorded acceleration data revealed two phases of the impact. The first was relatively mild, probably a consequense of the bursting.

The sharp peak of the curve for the acceleration of the head was missing. In the second phase the acceleration peak did not occur until after the chest had hit the instrument panel *i.e.*, the head has bent forwards and hit the instrument panel. The film shows that the bag bulges out to one side (right of cadaver). It does not affect the position of the head relative to the trunk.

Autopsy findings: No demonstrable external lesions. Third and fourth left ribs fractured at level of anterior axillary line. First right rib torn from sternum.

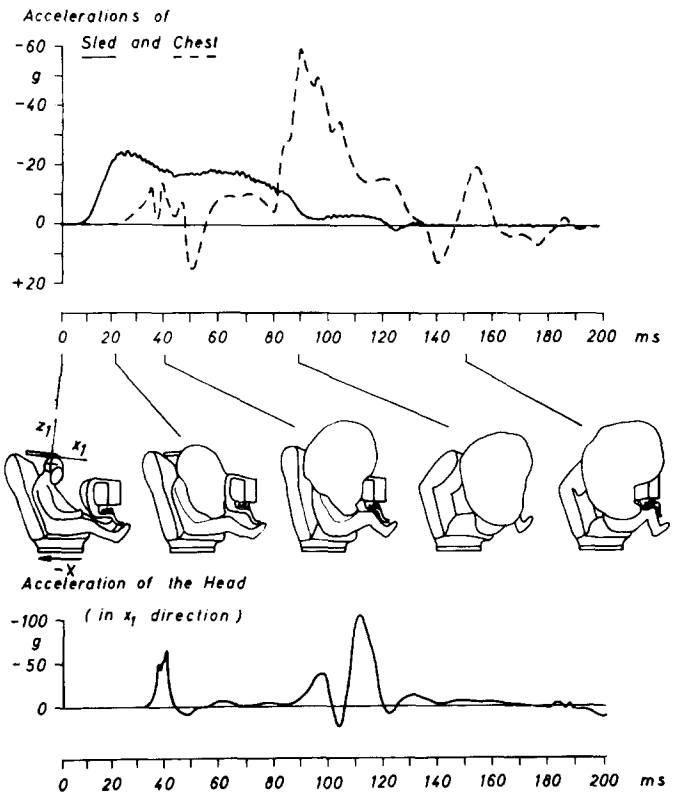

Fig. 7. Accelerations in experiment 2

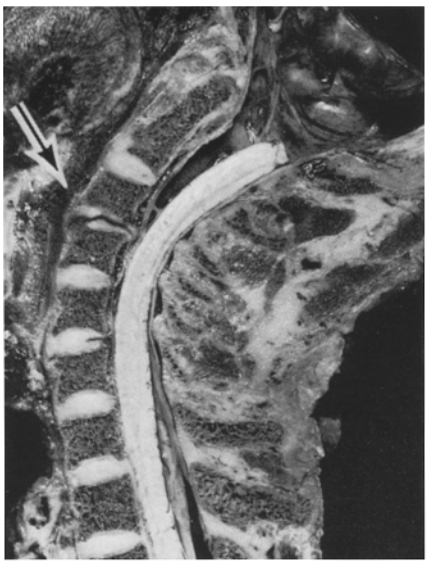

Fig. 8. Experiment 2: Cervical spine injuries

Laceration of anterior part of capsule of right sternoclavicular joint. Blood between posterior part of the occipital foramen magnum and atlas. Laceration of intervertebral disc between third and fourth cervical vertebrae. Anterior gaping fracture of the body of the fourth thoracic vertebra. The fracture continues into the intervertebral disc between the fourth and fifth thoracic vertebrae. Small impression fracture on the right side of the left patella.

Experiment 3

Air bag model Olin (280 l).

Man aged 47, 175 cm, 85 kg. Strong bodybuild. Cause of death: Barbiturate poisoning.

In this experiment the acceleration of the head was less than in any of the other tests. Here, the effect of the air bag was optimal and the cadaver was that of a strong man with the result that no serious injuries had occurred. It is recognised from the acceleration of the chest that here, too, there occurred a backward jerk ($-x$), after which the chest was again thrust against the bag (at 70—80 msec) and did not come into contact with the instrument panel until at 90—110 msec.

The curve for the acceleration of head did not show any remarkable peak in either phase.

Autopsy findings: On the anterior surface of the skin of the neck was grazed in a transverse 14 × 2 cm area. A similar area was seen in the front of the chest and of the right upper arm. Otherwise no injuries.

It is seen from the film that the head did not hit the instrument panel or the back of the seat. On the other hand, the bag to the right of the cadaver was extremely expanded when the head, which was held to the left of the midline, was thrust against the bag. In this case, then, an extreme blow against the head in the initial phase was warded off.

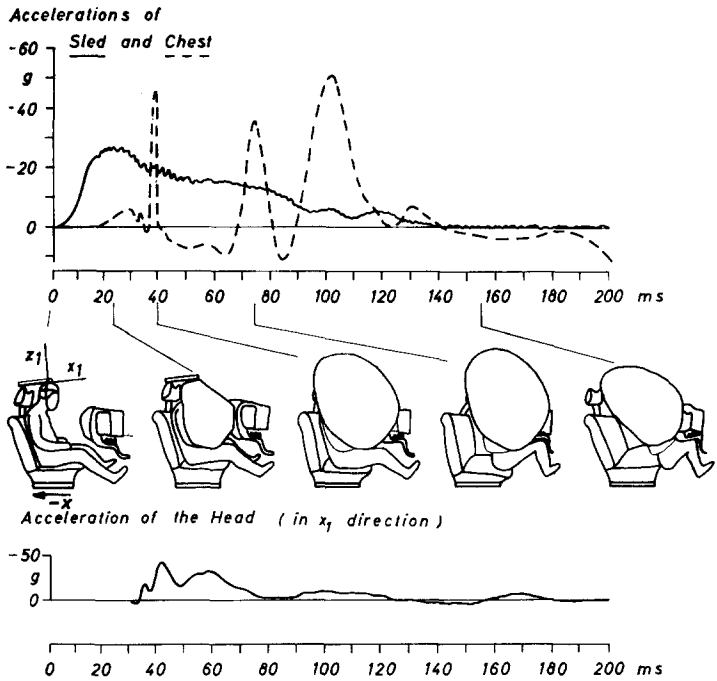

Fig. 9. Accelerations in experiment 3

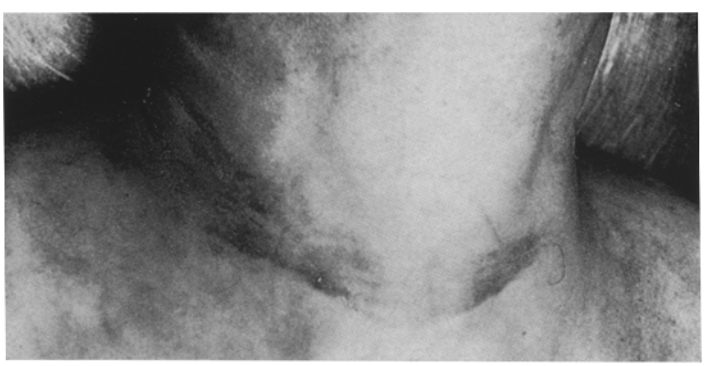

Fig. 10. Experiment 3: Skin abrasions on the neck

Discussion

In all of the experiments the acceleration of the chest was biphasic. The high acceleration of the head when thrust against the bag in exp. 1 was striking. This probably contributed to the injury of the soft cerebral meninges in the environment of the superior cerebral veins owing to movement of the surface of the cerebrum against the dura and to respectively retroflexion and hyperextension of the cervical spine with the typical lesions as a result. In case 3 no such injuries were seen. In this experiment the acceleration of the head was not extremely high. In-

juries to the surface of the brain in the area of the longitudinal fissure of the cerebrum (rupture of superior cerebri veins and surrounding tissues) in living persons are often associated with lesions of the brain stem (Voigt and Saldeen). Brain stem lesions cannot, however, be produced in cadavers.

Case 2 shows the risks involved when the bag does not function properly.

These pilots test do not, of course, warrant any conclusions concerning the protective effect of air bags. The results nevertheless suggest that in future in experiments with air bags special attention must be given to the cervical spine and the superior cerebral veins. Examination of the bridging veins and their environment requires opening of the head ad modum Flechsig (Voigt and Saldeen).

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