THE AGE AS A FACTOR INFLUENCING SOFT TISSUE INJURIES

by

Georg Schmidt

Institut für Rechtsmedizin der Universität Heidelberg, BRD

Coming from Heidelberg I can say with pride that some of the important insights in the field of biomechanics came from Heidelberg authors. From this group I would like to recall three: Karl Heinrich Bauer, the famous surgeon and scientist who 60 years ago as his first paper published an article concerning liver ruptures and their cause. In 1946 he was Rector magnificus of the University of Heidelberg and later on director of the Deutsches Krebsforschungszentrum and spiritus rector of a research unit in traffic accident traumatology (head was his assistant Prof. Gögler, well known for his review article "Klinik, Mechanik und Biomechanik des Unfalls", 1968). Hans Schaefer, a physiologist, discovered 35 years ago the main cause of death after blast injury: arterial embolism.

The following two examples can serve to introduce my paper: the dynamic injury of soft tissues and organs may be a destruction in the area of impact, but also can work through indirect changes of essential organ functions: loss of blood, loss of O_2-transport by air embolism, direct cerebral dysfunction as the main cause of death. After a heavy impact we see other causes of death: infection, organ function deficiency, suffocation, heat exposition, intoxication and so on. My paper will now deal with direct injuries to organs, influenced by the age of the victim.

In ageing bone we are familiar with the phenomena of decreasing stress and strain tolerance to a bending force. We know that osteoporosis not only in very old men but already at the age of 40 makes a remarkable difference if compared with younger people.

A slide with our results from 212 cadaver tests and simulations of frontal impact shows you the distribution of injuries. Rib cage fractures are the most important but numerically in second place. We nearly always found muscle-tears (83,1 %) - I am referring now to damage to soft tissues - then contusions and lacerations of the anterior abdominal wall follow with 63,7 %, ligaments of the vertebrae 61,3 %, intervertebral discs 60,8 %. According to the AIS these injuries are for the most part minor and would be rated as 3. More severe injuries are plexus brachialis lacerations (10,4 %), mesenteric or peritoneal tears (8 %), liver ruptures (7,5 %), lung contusions (3,8 %), gut perforations (3,3 %), grouped under 10 %. Under 3 % kidneys, spleen, great vessels; under 1 % heart, pancreas, urinary bladder and suprarenal glands (Gg.Schmidt et al., 1979).

The age is the leading factor influencing severity and number of injuries. We can learn from these tests, that a tolerance limit, expressed in acceleration values between 10 and 25 g is closely dependent on the subjects age. 25 g is a limit for the chest of a young man (ca. 20 years old), sustaining an impact through frontal crash and restrained by a three point belt (45 km/h). The tolerance limit is only 10 g when a 45 years old individuum is exposed to the same loading conditions.

In comparison the chest can sustain significantly higher loads than the soft internal organs, whose ability to withstand trauma is dependent on the integrity of the thorax. Once the stability is lost the resistance of the soft internal organs is minimal. In our studies we were able to determine the relationship between age and trauma and observed the following:

The rib cage of a small child has a very high elasticity but limited stability. Deformations in x-direction can reach 10 cm without fracturing ribs. Four to five centimeters deformation are indeed sufficient to destroy the rib cage of an older person of ca. 60 years. In both cases the inner organs are unprotected against pressure and dislocation.

This is in accord with those reports on lung contusions derived from clinical observations: Among 155 patients with lung-thorax injuries Irlich and Schulte (1979) found 19 suffering from isolated lung contusions, with an average age of 20 years. Patients with combined injuries (n = 136) had an average age of 42 years! Nonpenetrating injuries are proposed. Skin is in most cases unlacerated, with only superficial tears or bruising.

The biomechanical properties of the rib cage are of decisive import, when damaging factors of the lungs and of the heart and also of the mediastinal organs are considered. In this case we also must regard the ageing of lungtissue, which is of course a factor of only minor importance.

The relationship between volume resistance breaking and vital capacity (Islam et al., 1978) shows close correlation with age. This is caused not only by the stiffening of ageing lung tissue but more by restricting the joint movements of the ribs, resulting together in senile emphysema. Other pathologic findings of intrathoracic organs such as pleural fibrosis, lung induration and so on have an additional but only secondary influence; pathological conditions, whose diagnosis is to a great extent dependent on the experience and standpoint of the investigator and for which practicable means of expression in quantitative terms are lacking.

The traumatic heart damage, caused by non penetrating dynamic impact, is considered as resulting from very short impulses against the sternum. As explosion pressure peak can have a disturbing effect on heart circulation with enlargement of venous vessels and constriction of the coronary arteries (Rössle (1942, 1943); Rössle and Benzinger (1942); Schaefer (1944)) - similar findings were made after blunt mechanical impact. Later on fibrotic plaques in the myocard are found if the injury is survived.

As a consequence of the statistically demonstrated cumulation of pathological findings during life we should expect a greater vulnerability of the heart and in a similar manner of other inner organs in the elderly. The newest review article we have, brings nothing about age dependence of blunt traumatic heart and aorta damages (Gremmel et al., 1979).

The clinical evaluation is not always correct and postmortem analysis is not always foolproof. The wide spread incidence of cardiovascular diseases explains the inclination of medical experts to declare any degeneration of vessels or muscular tissue as nontraumatic. Traumatic residues otherwise found after cardiac arrest in sudden death cases are considered nonfatal.

Groundwork in the biomechanics of soft tissues and internal organs represents a broad field requiring intensification of research efforts in the near future. Investigations on the liver, spleen and the kidneys were conducted by Fazekas et al. (1971, 1972). This hungarian forensic pathologist performed extensive measurements on freshly prepared cadaver organs after having first done work dealing with the biomechanic properties of skin.

Static loading of isolated livers led to rupture after a deformation distance of 2,26 ± 0,59 cm, mean pressure was 168,5 ± 63,8 kp (n = 42). For the spleen he showed 44,0 ± 21,61 kp, deformation distance was here 1,0 ± 0,4 cm. The given numbers were reached after the first tears through capsule and tissue.

Multiple ruptures resulted with a load of 319,81 ± 90,81 kp (liver) and 3,38 ± 0,18 cm deformation.

As opposed to the calculated values he found minor pressure limits for elderly persons with liver fibrosis, however the kidneys having degenerative changes were more resistant!

Our own experience is: the fibrotic liver can sustain more pressure per unit area than the healthy one. It follows that degenerative liver fibrosis sometimes is concomitant with elasticity deficiency. K.H.Bauer (1919) subdivided four kinds of liver rupture:

1) subcapsular bleedings
2) tissue tears (single or multiple)
3) total rupture
4) central rupture

The central liver rupture (Wilms, 1901) may be of special clinical interest because of late diagnosis and life threatening late sequelae, such as abscess.

In a similar manner the blunt trauma of the thorax which gives rise to lung contusion has many clinical aspects respectively consequences:

1) alveolar damage and focal bleedings
2) edema of the lung
   as a consequence of 1) and 2):
   decreasing oxygen saturation of the blood
3) shunt, secret enrichment, atelectasis
4) infection

It is easy to understand why old persons are more prone to a final dangerous and lethal state.

Soft organs are very sensitive to blunt impact. Energy absorbing factors which protect these important parts of the body are the surrounding structures and tissues: skull, rib cage, muscles, fat and connective tissue, skin, clothes. The more fat layers lying between the liver and the area of impact, the greater is the tolerance limit against blunt impact. In the same manner heart and lungs are better protected by a thick muscle and fat layer.

As you can see the relative significance given to various risks ("Risikofaktoren") from the point of view of biomechanics is often radically different from the emphasis given from the standpoint of cardiovascular diseases.

Cerebral damages.

Though our knowledge of the physiology, pathology and even the biomechanics of the brain is in some areas considerable the age factor has received little attention.

A different picture arises from the relationship of skull to brain in ageing. The skull exhibits only limited growth during the second half of adult life. Osteoclastic function of the dura mater gives way to the skull contents. On the other hand atrophy of the brain is not uncommon in the last decennia. As a result we see more cerebrospinal fluid surrounding the brain and also protecting it. Changes in the mechanical properties of brain tissue is not significant during the life.

A major variable influencing injury involves the ability of the skull to dissipate energy. Its deformation plays a role in producing conditions such as contre coup or coup, contusions and concussion.

Typical age depending injuries are:
1) traumatic edema in childhood
2) contre coup in adult stages (Welte, 1948)
3) epidural hematoma in adolescents and elderly persons

ad 1)
Edema without skull fractures arises after an impact because of growing brain in connection with poor fibre structure within a thin and deformable skull. Smooth membranes are rich in fluid.

ad 2)
From adolescent age with a maximum brain weight (due to the continuing evolution we can now see brains weighing 1800 g and more!) until 30 years the possibility of contre coup is the greatest. From 30 to 60 the brain continously undergoes change as part of the ageing process. Coupled at first with a certain loss in weight, then in the period between the ages of 60 - 90, the tissue changes lead to a significant atrophy. The more fluid is around the brain the better cortical tissue is protected against negative pressure-induced lacerations. Never we find contre coup in cortical areas lying under fluid layers.

ad 3)
The epidural hematoma as a consequence of rupture of the arteria meningica media (or similar artery) exhibits the strongest age-dependence: It occurs only during life periods in which dura and skull are attached. These injuries occur as a result of fracture to a bone which is crossed by the artery. Children have an osteoplastic dura mater, old people an osteoclastic one. In both cases a consequence is the attachment of the fibrous tissue harbouring the artery.

Quality and extent of injuries must be seen in a threefold manner:
1) energy disspation
2) direction of impact
3) age and constitution of the victim

Among 53 subdural hematomas 37 patients were older than 50 years. Krauland (1961) indicates the greater rigidity of vessels and the higher blood pressure as possible cause. Lausberg (1977) counted up to 14 years 129 impressive fractures, between 15 and 49 years 212, but only 32 above 50 years.

Therefore it is of great interest for future studies in biomechanics to analyse not only forces and kinematics but also anthropometric and structural properties of the human beings.

Summary

We now are familiar with the age depending changes of bones leading to some biomechanical or pathomechanical (Kulowski, 1960) implications. About soft tissue, especially the very important organs, we have not yet enough data. During life not only the single organ but more the mass relation of the surrounding and protecting layers vary. Some influence factors arising from age dependent properties of healthy and sick organs are discussed, but only fragments I could present.

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Prof.Dr.med.Georg Schmidt

Institut für Rechtsmedizin
der Universität Heidelberg

Voßstraße 2, D 6900 Heidelberg