External injuries to the larynx

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Abstract

An attempt was made to gain as accurate a knowledge as possible of the mechanism of progress of an injury to the larynx, to determine the factors on which the extent of the post-traumatic changes depend, and to define the interdependence of these factors and the clinical changes. Research was carried out along three converging lines. Experimental studies, by means of presses and pendulums constructed for the purpose, were made on the action of dynamic and static forces on forty larynxes dissected out from cadavers. The clinical investigations were made on forty-seven hospitalized patients and seventeen out-patients in the Otolaryngological Clinic of the Cracow Academy of Medicine in 1960–70. These two lines of research were complemented by analysis of the factors on which the extent of the post-traumatic changes depend from the point of view of physics and mechanics with regard to the larynx.

Introduction

Not much is known about the problems of laryngeal injuries, though in clinical practiçe they present a serious diagnostic and therapeutic problem, and the disturbances in voice and the contraction of the respiratory passages arising after injury in a large percentage of cases indteaci their importance. The specific structure of the larynx, the location and suspension of this organ, and its particular function in the human organism cause the progress and consequences of the action of an injury to differ from the mechanism and sequelae of injuries affecting other parts of the body. The action of mechanical, thermal, chemical, electrical, or radioactive factors may occasion external injuries to the larynx.

These injuries may be contracted in accidents when travelling or at work, by deliberate injury or attempted suicide. External injuries to the larynx caused by mechanical factors form the most numerous group of cases, as may be seen from clinical practice or data from the literature.

Subject and method of studies

Larynxes from human cadavers, excised up to 24 hours after death, were the subject of experimentation. The age and sex of the donors were known. The larynxes were freed from tissues not belonging to them anatomically and then measured.

The experiments required specially constructed apparatus: mounts,

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presses and pendulums (Figs. 1, 2, and 3). The larynx was fixed by means of elastic and hooks on a mount. Pressure and blows were exerted by means of a press constructed as follows: a tripod formed the stationary part. A muff with a screw was placed where the legs met. The mobile part

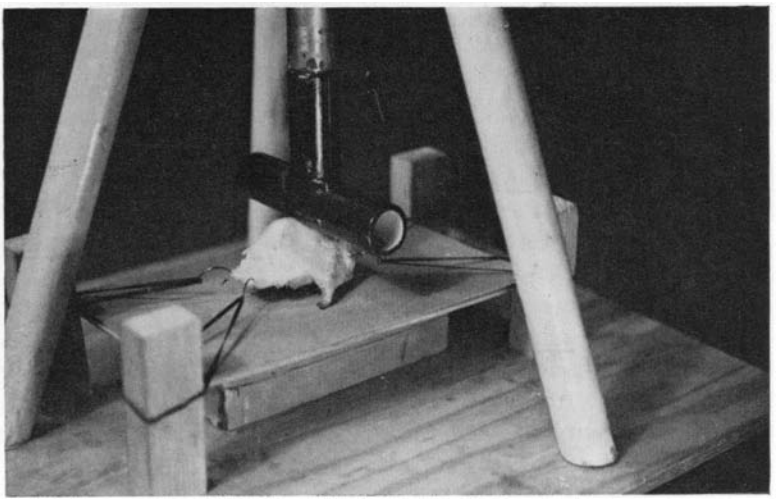


FIG. 1.

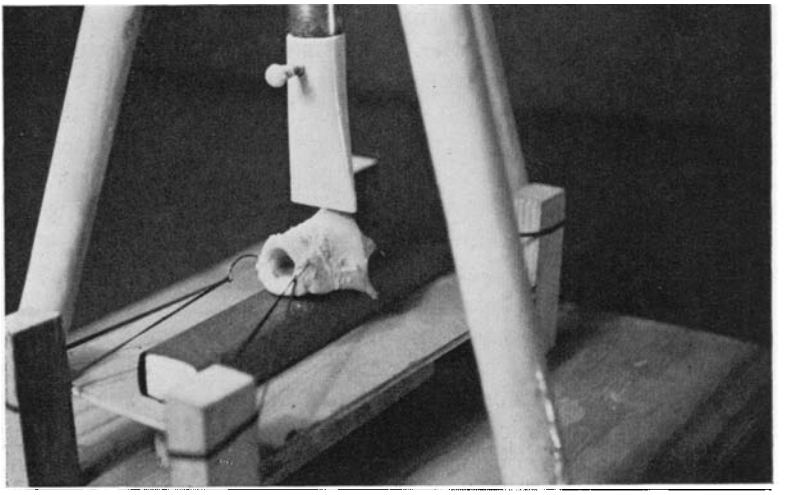


FIG. 2.

of the press, a pivot, emerged through the muff. At one end of the pivot was fixed an end piece for contact with the larynx and at the other a platform on which weights were placed. Two end pieces were used, one in the form of a reversed letter 'T' and made of tubes 25 mm. in diameter, and the other in the shape of a wedge of which the sharp end was about

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2 mm. thick. The press fulfilled a double role: it enabled pressure of a selected weight to be exerted by the pivot and the appropriate end piece, as well as a blow with the movable part of the press at a determined height by using the countering screw in the muff.

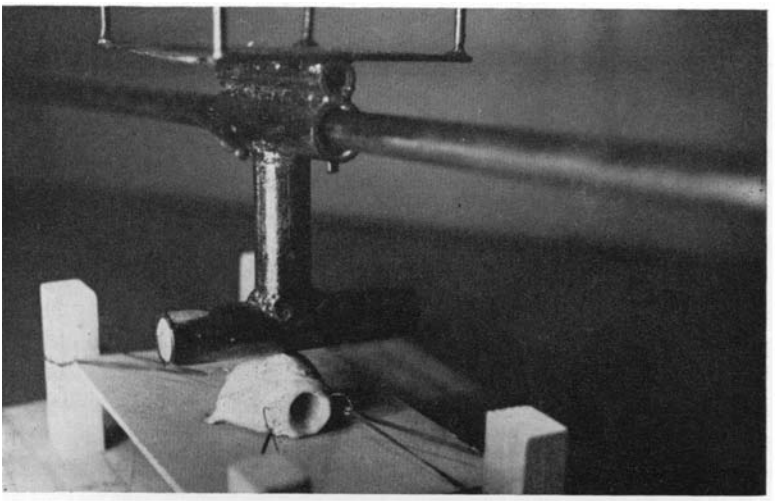


FIG. 3.

The arm of the pendulum was made of a metal tube on which a striker was so placed that it could be fixed at any arbitrarily chosen place on the arm and also given an additional load. In experiments with the pendulum, the endpieces for contact with the larynx were identical with those used in the press.

The mounted larynxes were supported in two ways; in the first version the support was placed in the notch between the laminae of the thyroid cartilage and in the second version the whole posterior surface of the larynx adhered to the mount.

The blow or pressure was aimed at three sites: the region of the notch in the superior thyroid cartilage, the anterior border in the centre of the thyroid cartilage, and the arch of the cricoid cartilage.

In clinical examinations special attention was paid to the circumstances of the injury, determination of the order of magnitude of the forces leading to the injury, the nature of the instrument of injury, the early and late clinical consequences of the injury, and the method of treating the patients. More interesting cases of post-traumatic changes were photographed with a Storz apparatus for indirect laryngescopy.

Theoretical analysis was made of the following factors, on which the extent of the post-traumatic changes depend: the influence of the force of the injury, the area of action, the magnitude of the kinetic energy of the instrument of injury, the degree of transmission of the kinetic energy

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through the larynx, the influence of the elasticity of the tissues, the influence of factors counteracting the injury.

Results

For the experimental studies forty larynxes were used (nineteen female and twenty-one male), taken from cadavers aged from 17 to 80 years. No morbid changes were found in these larynxes on inspection. Measurements of the size and weight exhibited very marked differences between individual larynxes, sometimes reaching up to 50 per cent. Differences were also found in the shape and hardness. On account of such markedly differentiated research material and because of the difference between an experiment and injury to living subjects, the complicated calculations of the magnitude of the force used in each variant of the experiment were given up, while attention was concentrated on the conditions which augment or decrease the effect of the action of the force of the injury.

When the larynx was supported between the laminae of the thyroid cartilage and pressure was exerted in the region of the thyroid notch, a pressure of 3–7 kg. caused compression of the laryngeal lumen at the level of the arytenoids and aryepiglottic folds in all larynxes. In this phase the aperture in the laminae of the thyroid cartilage varied within the range of 145°–165°. Increasing the weight of the pressure did not initially change this state, but further rises to 15–20 kg. very often led to the closure of the larynx under the arm of the weight acting on it. Fractures or ruptures were not obtained in these conditions. Directing the pressure to the centre of the anterior edge of the thyroid cartilage led to compression of the laryngeal lumen with the same ease as before, and in six cases the thyroid cartilage was successfully ruptured by a pressure of 15–22 kg. at the site of fusion of the two laminae on the anterior border. The process of ossification was fairly advanced in these larynxes.

When the position of the larynxes on the plane was such that they were equally supported by the free borders of the laminae of the thyroid cartilage, the progress of pressure depended to a great degree on the elasticity of the larynx, and so on the degree to which the process of ossification was advanced. Compression of the laryngeal lumen at the level of the arytenoids ensued when the pressure in the vicinity of the thyroid had a weight of 3–9 kg. and the angle of aperture of the laminae of the thyroid cartilage was 155°–170°. Increasing the weight then also caused the larynx to shift in the direction of its narrower part under the arm of the weight in action.

Transferring the action of the weight to the centre of the prominence of the thyroid cartilage caused a marked rise in the number of cases in which rupture or fracture was successfully obtained. A pressure of 3·5–7·5 kg. was enough to flatten an elastic larynx almost completely on the

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mount. In harder, more rigid larynxes, rupture or fracture of the thyroid cartilage was usually achieved at the site of the fusion of the laminae on the anterior border; the lowest weight to cause fracture was 11 kg., and the most resistant of the larynxes tested was fractured by a pressure of 24 kg. In this group the angle of aperture of the laminae of the thyroid cartilage did not exceed values of 160°–166°.

Pressure directed against the arch of the cricoid cartilage usually brought about rupture or fracture; fracture did not ensue in only four cases in spite of compression of the lumen of the cricoid cartilage. These were larynxes from the cadavers of the youngest subjects. When the weight of the pressure was augmented, initially the anterior-posterior dimension was decreased and the opposite dimension increased. Then rupture and displacement of the arch occurred suddenly; the most frequent site at which continuity was broken was the transition of the arch into the facet of the cricoid cartilage. The weight of pressure leading to fracture of the arch varied from 5 kg. to 14·5 kg., and the average decrease in the anterior-posterior dimension was 30–35 per cent.

The next stage of the tests was dropping a determined weight on to the larynx from a distance of 30 cm. For this the endpiece on the pivot of the press was changed. Besides the normal endpiece in the form of a reversed letter 'T', a wedge-shaped endpiece with the sharp end 2 mm. was also used. It was found that elastic larynxes do not undergo fracture or rupture even when struck by a weight of 10 kgs.; these larynxes were only flattened on the mount during pressure, and then returned to their original shape. Hard larynxes, with advanced ossification, underwent fracture; the weight needed for fracture by dropping from a height of 30 cm. was as much as 16 kg. It was observed that larynxes of relatively large longitudinal (slender) dimensions, fairly hard, and with a more acute angle of aperture of the thyroid cartilage laminae, were more resistant than the others.

The wedge-shaped ending of the pivot of action of the weight in elastic larynxes susceptible to pressure caused indentations and lacerations by a blow from a height of 30 cm., while in hard larynxes with advanced ossification the penetration and cutting action were distinctly less, but fracture ensued just as by the action of the endpiece shaped like an inverted 'T'. It was rather easy to achieve fracture of the cricoid cartilage by dropping a weight on it, and a lesser weight was needed than for fracture of the thyroid cartilage. The wedge-shaped endpiece transmitting the weight to the larynx led to fractures more quickly and easily.

In the next stage of experimentation, the pendulum was applied. Observations were difficult on account of the speed of the process of injury, and in addition there were difficulties in hitting exactly that part of the larynx the pendulum was aimed at, so that in the discussion the larynx has been considered as a whole. It was seen in this experiment that

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it was possible to obtain fracture or rupture of the larynx merely by making use of the weight of the moving pendulum itself. Its weight, together with the impact, amounted to 2 kg. Obtaining the effect of action, i.e. fracture, depended on the distance from which the pendulum was released against the larynx. This distance, when the angle of deviation of the pendulum was the same, was increased by removing the striker on the arm further from the pivot of the attachment. It was further observed that the destructive effect of the pendulum could be augmented by giving an initial impetus to the pendulum with the hand. In the subsequent stage of the investigation the pendulum striker was loaded with an additional weight of 1 kg., which also distinctly increased the destructive power of the pendulum.

Approximate calculations of the force of action of the pendulum at a weight of 3 kg. and selected distances, heights, and rate of fall were made. It was estimated that the greater the last two values, especially the rate of fall, the greater the striking force. For instance, dropping the pendulum from a height of 0·5 m. at a speed of 3 m./sec., gives a striking force of c. 6 kg.; by merely changing the speed to 10 m./sec., from the same height, the striking force is increased to c. 33 kg.

Discussion

Only a few essential remarks will be presented from the theoretical analysis of the mechanics of injury. The magnitude of the force of the injury is directly proportional to the magnitude of the mass and the negative acceleration or retardation. The violence of the action of the force is decided by the time taken to lose the initial speed; the less this time and nearer to zero, the more the magnitude of the force will increase.

The action of the force on the area has been identified as a tension. Under the influence of the action of the force on the larynx the area on which this force acts is increased as a result of the widening of the angle of the thyroid cartilage laminae and the regression of the larynx into the interior of the soft cervical tissues. As the area becomes larger, the magnitude of the tension lessens.

The kinetic energy of the striking object depends mainly on the square of the speed, from which it may be concluded that an increase in speed has a more rapid effect on the rise in E_k than an increase in mass. This phenomenon is of importance because in some cases it leads to earlier interruption of the continuity of the tissues, before the larynx can be supported by the spinal column, and the abruptness of this phenomenon does not allow the protective factors to come into action.

In the larynx the degree of propagation of the kinetic energy transmitted by the injury is a very complex problem on account of the specific and complicated structure of the organ from elements differing in cohesion, density, and elasticity, as well as the specific location of the individual

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structural elements. Kinetic energy, in such a system, is changed chiefly into work causing permanent deformation and so impairment, and to a lesser extent into resilient deformation. For this reason also the frequency of injuries to the particular tissues of which the larynx is constructed depends to a marked degree on the histochemical structure. The elasticity of the tissues has a marked influence on the extent and nature of the injuries; the more elastic the tissues, the less often they suffer injury. The framework of the larynx is constructed of cartilages differing in their degree of elasticity, depending on the histological structure and the advancement of the ossification process. Increased hardness through ossification lessens the elasticity but increases the mechanical resistance. When the resistance of tissues with little elasticity is overcome, injuries occur in the form of fractures and ruptures.

Among the factors counteracting injury, the location and fixture of the larynx in the cervical soft tissue with the possibility of active or passive displacement is one of the most important. The defensive activity of such a system is multifarious; it lessens the violence of the action of the force, enlarges the area of action and lengthens the path of action of the force. The geometrical structure of the thyroid cartilage causes the vector of force to break up into its components and so in effect the dispersion of the direction of the main force. Further defensive factors seem to be the situation of the larynx, set back from the most advanced parts of the head and thorax, the possibility of bending the head forwards over the thorax, and the defensive reflexes of the person.

The results obtained by these lines of research have shown an actual connection and interdependence in many points, and have enabled some observations to be formulated.

The larynx has a relatively complex and delicate structure, and its weight of c. 40 g. constitutes a 1/1700th part of the weight of the human body. This does not favour resistance to the action of external factors. There are considerable individual differences in the size, weight, shape, elasticity and hardness of the larynx, depending among other things on body structure, sex, age, and individual characteristics. These differences influence the final effect of the action of injury. The extent of the post-traumatic changes in the larynx depends on a complex of factors which may be divided into the following groups: (1) factors resulting from the physical properties of the object causing the injury; (2) factors resulting from the physical and biological characters of the larynx; (3) the complex of factors protecting the larynx. The mechanism of the process of injury to the larynx is, on account of the features of its anatomical and histological structure, more complicated than in bodies with a uniform material and structural formation.

The extent of the damage to the mucosa certainly influences the origination of post-traumatic contractions of the larynx, as well as

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fractures and ruptures. Apparently they act as 'barriers' in cicatrization processes, so that obliterating processes in the larynx occur most frequently at sites without mucosa; the subglottic region and the region of the vestibular folds (saccular folds) are the most frequent sites of cicatricial changes.

Conclusions

1. The mechanism of injury to the larynx is a complex problem. In every case various influences should be taken into consideration: the physical properties of the instrument of injury; the anatomical, geometrical and physical properties of the larynx, and a complex of protective factors.

2. The violence of the process of injury is one of the fundamental factors conditioning the extent and nature of the post-traumatic changes.

3. The frequency of damage to particular sites in the larynx is not accidental, but conditioned by both the physiochemical structure and also the nature and extent of the injury.

4. Not only the fracture of the cartilages, but especially the process of healing of the tissues lining the lumen of the larynx, particularly the mucosa, influences the origination of post-traumatic contractions of the larynx.

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