ACTA ORTHOPAEDICA SCANDINAVICA
SUPPLEMENTUM no. XXIII

FROM THE DEPARTMENT OF ORTHOPAEDIC SURGERY
(HEAD: G. WIBERG, M. D., PROFESSOR OF ORTHOPAEDIC SURGERY
UNIVERSITY OF LUND) *AND FROM THE DEPARTMENT OF ANATOMY*
(HEAD: C.-H. HJORTSJÖ, M. D., PROFESSOR OF ANATOMY
UNIVERSITY OF LUND), LUND, SWEDEN

STUDIES IN SPONTANEOUS ATLAS DISLOCATION

BY

SVEN WERNE

EJNAR MUNKSGAARD
COPENHAGEN 1957

Translated by Mr. L. James Brown

Printed in Sweden

HÅKAN OHLSSONS BOKTRYCKERI
LUND 1957

INTRODUCTION

In March 1953 a girl, aged 4 years, complaining of pain in the neck and showing acquired torticollis was seen at the Orthopedic Department, University Hospital, Lund. Investigation revealed dislocation of the atlas (luxation or subluxation of the atlas), *i. e.*, a dislocation of the atlas in relation to the epistropheus with consequent torticollis and contracture of the dorsal musculature of the upper neck.

Subsequent literature studies soon revealed divergence of opinion about the underlying mechanism of dislocation of the atlas and the interpretation of the clinical picture as well as about the most suitable method of treatment. Moreover, the data available on the anatomy of the occipito-atlo-axoid joints and especially on their mechanics were either vague or contradictory.

It was in an endeavour to fill this gap in our knowledge that the present investigation was started, the purpose of which was to elucidate the normal anatomy of the craniovertebral joints and the sequence of events in the development of so-called spontaneous dislocation of the atlas.

CONTENTS

Part II

ATLAS DISLOCATION

THE CRANIOVERTEBRAL JOINTS

Chapter I

GENERAL JOINT MECHANICS

The understanding of the mechanics of a given joint requires good knowledge of the mechanics of joints in general as well as of the anatomic features of the joint to be studied. However, it is not intended to extend the scope of the present investigation to include a detailed description of the mechanics of various types of joints. Therefore, suffice it here to give a brief description of those types of joints of relevant interest. Readers interested in further details are referred to the works of R. FICK and HJORTSJÖ. Unless otherwise stated, the data given below on the mechanics of some fundamental types of joints are based on investigations by HJORTSJÖ.

FUNDAMENTAL TYPES OF MOVEMENT

Since movement always occurs in relation to one, two or three of the three dimensions of space, movement is described in relation to three main axes. In human anatomy the axes are: the *transverse axis,* the *sagittal axis,* and the *longitudinal or vertical axis.*

Two fundamental types of movement are distinguished: *rotation* and *translation.* Rotation is to be understood as movement about an axis, translation as movement along an axis.

If there is translation along, as well as rotation about, one axis, the joint is said to have two *degrees of freedom* in relation to this axis. A joint can thus have more degrees of freedom than axes.

SOME TYPES OF JOINTS

When possible, the movements of a joint are described in relation to the above-mentioned three axes. The joints are

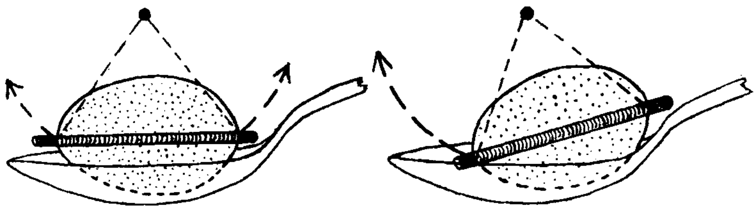


Fig. 1. After HJORTSJÖ.

therefore classified according to the possibilities of articulation as *uniaxial, biaxial* or *triaxial.*

A ginglymus or hinge joint is a uniaxial joint which permits rotatory movement only. The articular head often has the shape of a cylindric rod.

A *screw-joint* is a uniaxial joint allowing rotation and translation. Here the movement resembles that of a nut about its bolt, the bolt representing the articular head and the inner surface of the nut the articular cavity.

A *ball-and-socket* joint permits movement about three axes intersecting one another at the same point. One condyle is spheric and the other cup-shaped and of corresponding radius.

An *egg-joint* is a biaxial joint, whose axes cross one another at right angles in different planes.

R. FICK (1904—1911) tried to illustrate the movements of such a joint geometrically and arrived at the conclusion that a guiding contact between the articular surfaces is not possible, *i. e.* the articular surfaces are not able to stabilise the movement of the joint, and that such joints must therefore have "several axes of movement". If such a joint has only two possible types of movement, rotation about its axes, such as the occipito-atloid joint unit, this is, according to FICK, because of the checking function of its ligaments.

HJORTSJÖ (1952) compared a biaxial joint whose axes crossed one another at right angles in different planes with an egg in a tablespoon (Fig. 1). According to HJORTSJÖ, this joint permits two types of movement: rotation about its longitudinal

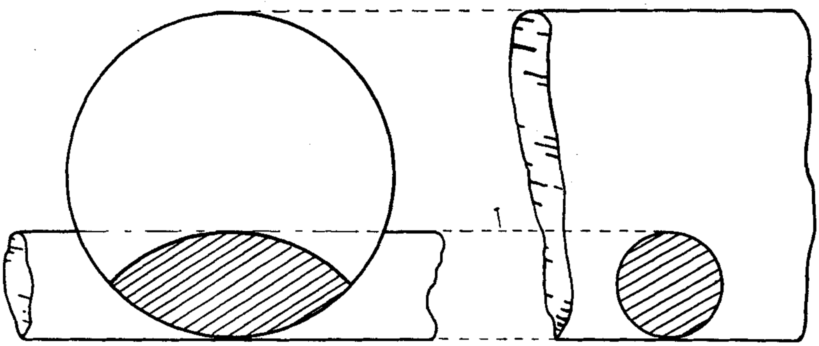


Fig. 2.

axis and rocking between the tip and the handle of the spoon (Broman & Hjortsjö). This example illustrates the approximate movement in the joint, but it is not sufficient in the study of the movement of the joint in detail.

The motion in a biaxial joint whose axes cross one another at right angles in different planes is of relevant interest, because the occipito-axoid joint unit appears to be of this type (Fick 1904—1911, Poirier & Charpy 1931, Broman & Hjortsjö 1952). The assumption that such a joint might be guided by ligamental function (R. Fick) appears less likely. The ligaments guiding motion about one axis would prevent movement about the other and ligaments guiding movement about the latter would prevent movement about the former and thereby all movement would be prevented. Therefore movement in such a joint must be guided by the articular surfaces; otherwise no such joint could exist.

A biaxial joint whose axes cross one another at right angles in different planes can be illustrated by starting with two cylindric rods representing movement about the respective axes. It is then possible to investigate what portions of the rods partake in rotation about both axes. It will be found that this body will be fusiform with the axis of the smaller rod as the

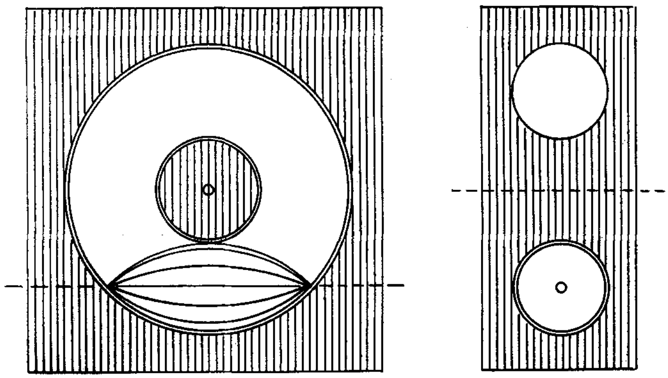


Fig. 3.

longitudinal axis, the radius of the larger rod being the radius of the longitudinal contour of the fusiform body (Fig. 2). If this fusiform body be allowed to rotate about its axes in a plastic mass, it will create a hollow in the shape of an annular tube with the small half axis of the fusiform body as the radius of the tube and the larger radius of the fusiform body as the radius of the outer contour of the tube. This gives two linear contacts between the fusiform body and the surface described by its movement, *e. g.* the inner surface of the annular tube (Fig. 3).

A joint of this type is guided by two bow-shaped linear contacts perpendicular to one another and probably represents the ideal joint whose axes cross one another at right angles in different planes. Guiding joint contacts are obtained, however, even if only the longer of the two arcuate linear contacts is present provided there is no play in the joint. A joint of this type is illustrated in Fig. 4.

It should, however, be mentioned that this physical illustration of the functional principles of a biaxial joint whose axes cross one another in different planes does not exclude possibilities of biologic variation such as surface contact due to the elasticity of the cartilage.

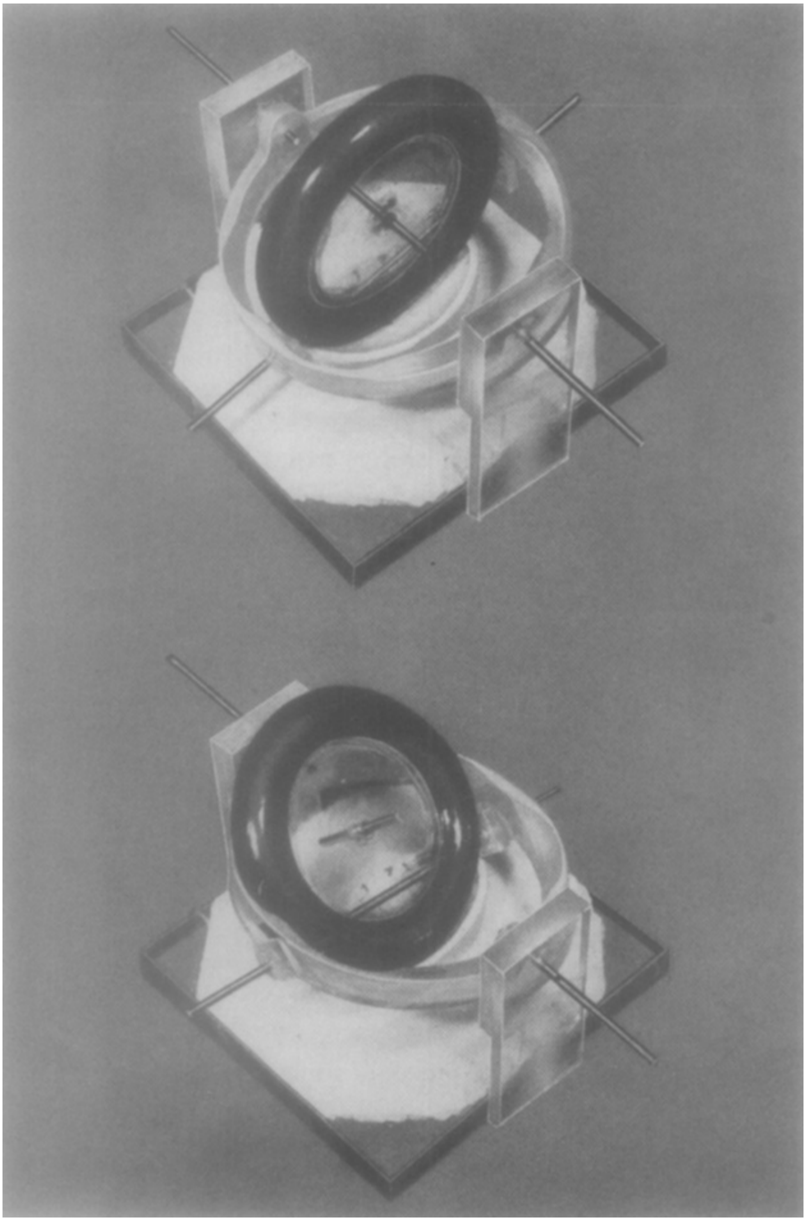


Fig. 4.

Chapter II

ANATOMY AND MECHANISM OF OCCIPITO-ATLO-AXOID JOINTS

ANATOMY

The anatomy of the occipito-atlo-axoid joints has been described in detail in several text books (R. FICK 1904—1911, RAUBER & KOPSCH 1922, SPALTEHOLZ 1929, POIRIER & CHARPY 1931). The nomenclature, however, varies from one author to another. This applies above all to the ligaments (HECKER 1923). A short survey of the anatomy of these joints might therefore be useful in order to avoid misunderstanding in subsequent sections. Here use will be made of the nomenclature employed by RAUBER & KOPSCH and SPALTEHOLZ with those modifications suggested by BROMAN & HJORTSJÖ (1952).

SKELETAL ANATOMY

Movement of the cranium in relation to the spine is controlled by two composite joints, the occipito-atloid and the atlo-axoid joints. Together they form a functional entity, the *craniovertebral joints.*

The *occipito-atloid joint unit* consists of two separate joints between the occipital condyles and the upper articular surface of the atlas on either side. They should, however, be regarded as parts of a single joint in that the occipital condyles as well as the articular masses of the atlas are connected to each other by osseous union.

The *atlo-axoid joint unit* consists of four separate joints, two intervertebral and two odontoid joints.

The two intervertebral joints are said to be characterized by the fact that the articular surfaces of the atlas as well as of the epistropheus are convex (HENLE 1856), which is, however, denied by HULTKRANTZ (1912) (see below). The joint capsules are loose and permit a wide range of movement.

The odontoid joints are: the anterior odontoid joint between the dens and the anterior arch of the atlas and the posterior odontoid joint between the dens and a transverse atlas ligament, the ligamentum transversum atlantis (see below), enclosing a cartilage. The anterior arch of the atlas and the transverse ligament surround the neck of the dens in a firm ring which has been called the annulus osteofibrosus by HECKER. This name had been accepted here because it describes how the atlas is fixed in relation to the epistropheus and the character of the odontoid joints as joints between points of pressure in this ring.

ANATOMY OF THE LIGAMENTS

The ligaments controlling craniovertebral movement can be conveniently divided into two groups:

A. OUTER LIGAMENTS

septum nuchae and *ligamentum longitudinale ventrale*, *membrana atlantooccipitalis dorsalis et ventralis*, and *membrana atlantoepistrophica dorsalis et ventralis*.

All these run longitudinally.

B. INTRASPINAL, SPECIAL LIGAMENTS

These ligaments have been described in detail by HECKER (1923). They are situated on the ventral surface of the spinal canal, where they form 3 separate though superimposed layers (I—III below). In dorsoventral direction these ligaments are:

membrana tectoria, ligamentum cruciforme and *the odontoid ligaments* (Fig. 5).

I. *Membrana tectoria* (Figs. 5 and 6 A) which is regarded as a well developed continuation of the deeper layer of the ligamentum longitudinalis posterior of the spine (SPALTEHOLZ):

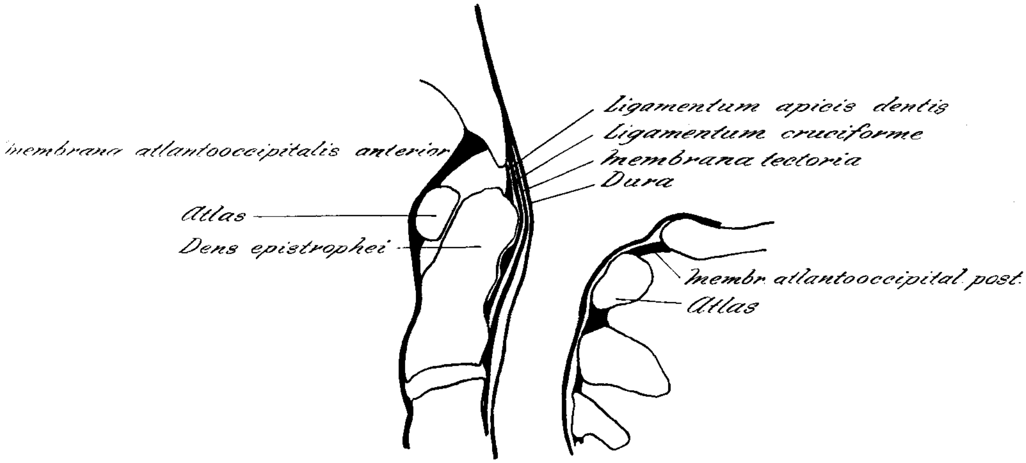


Fig. 5.

It is firmly connected to the corpus epistrophei and runs in cranial direction. After leaving the spinal canal it swings about 45° ventrally (Fig. 5), passes the anterior edge of the foramen occipitale magnum and is broadly attached to the cranial side of the clivus between the canales hypoglossi.

Three parts are distinguished:

1. *vertical ascending band* to the anterior edge of the foramen occipitale magnum (membrana tectoria according to HECKER).

2. *obliquely laterally ascending bands* to the anterior edge of the foramen occipitale magnum (le ligament occipito axo-idien latéral intrarachidien according to HECKER), and possibly

3. *accessory bands* running to the intervertebral capsules between the atlas and the epistropheus, *Arnold's ligament.*

II. *Ligamentum cruciforme* (Figs. 5 and 6 B) around the dorsal part of the dens and consisting of:

1. A strong horizontal ligament between the atlas condyles, *the transverse ligament,* which centrally encloses a cartilaginous body, against which the dens articulates via the posterior odon-

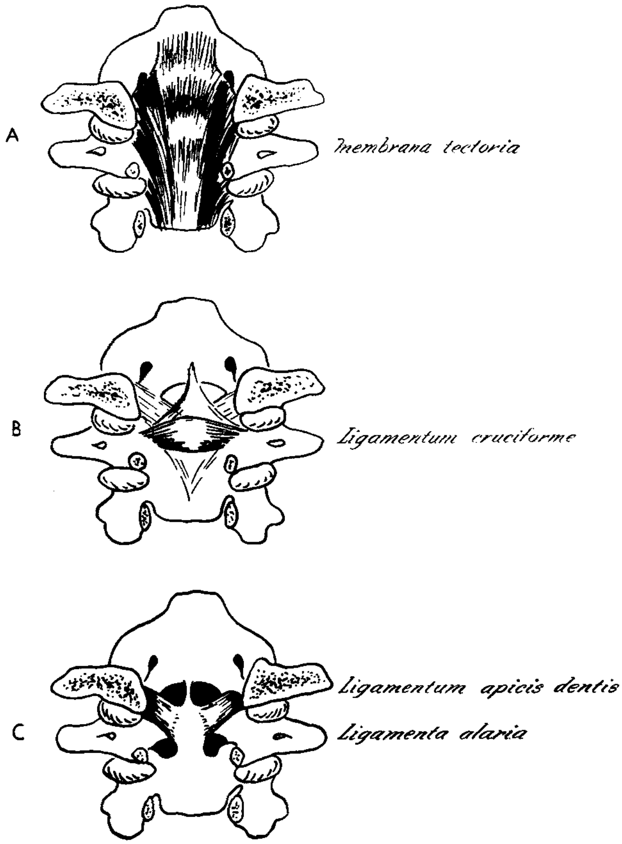


Fig. 6.

toid joint. Together with the anterior arch of the atlas the transverse ligament forms a ring, the annulus osteofibrosus, enclosing the collum dentis. The vertical or longitudinal diameter of the transverse ligament at the attachment is given by HECKER as much less than the corresponding diameter in the central portion, 3—4 and 7—8 mm respectively (Fig. 6 B). The transverse ligament has been compared with a section of a funnel, the mouth of which surrounds the collum dentis and the open part contacting the dorsal outline of the caput dentis.

In the ligamentum cruciforme three parts are further distinguished:

2. *a triangular descending band* to the corpus epistrophei,

3. *a triangular ascending band* to the anterior edge of the foramen occipitale magnum, and possibly

4. *an accessory band* ventral to the ascending triangular ligament and attached to the apex dentis, *Gruber's ligament.*

III. *The odontoid ligaments* (Figs. 5 and 6 C) consist of:

1. *The alar ligaments* extending from the dorsolateral surfaces of the caput dentis and attached to the medial surfaces of the occipital condyles. They form an angle in cranial direction with one another and, according to HECKER, this angle varies between 140° and 180°. This angle may be bridged by *an accessory ligament, Lauth's ligament.* In accordance with a description given by HENKE (1858), the alar ligaments are said to be taut when the head is directed forward.

2. *Ligamentum apicis dentis* between the apex dentis and the anterior edge of the foramen occipitale magnum. This ligament, according to HECKER, should be regarded as a rudimentary organ emanating from the chorda dorsalis, of poor development and of elastic consistence.

MECHANICS OF THE OCCIPITO-ATLO-AXOID JOINTS

According to R. FICK, our knowledge of the mechanics of the occipito-atlo-axoid joints is based on WEBER & WEBER's (1836) *Die Mechanik der Gehwerkzeuge.* Supplementary contributions to this field since made by SAPPEY (1853), HENLE (1856), HENKE (1858), MORRIS (1879) and R. FICK (1904—1911) form the foundation of modern concepts of the mechanics of these joints.

HENKE (1863) expressed the view that the occipito-atloid joint unit is a bi-axial joint with a transverse axis and a sagittal axis crossing one another in different planes. This conception is still accepted today (R. FICK, POIRIER & CHARPY, BROMAN & HJORTSJÖ).

HENKE (1863) determined the position of the axis by determining in sagittal and frontal sections through the joints the centres of the arcs formed by the outline of the joints, the joint profiles. He found the transverse axis to run through the centres of the mastoid processes and the sagittal axis through a point situated 2 to 3 cm cranial to the apex dentis (Fig. 7).

Since the occipito-atloid joint unit is built up of two joints and because the condyles of these two joints in sagittal direction are arcuate (cup-shaped), rotation, *i. e.* motion about a third axis, the vertical axis, is prevented in this joint (R. FICK). When turning the head, then, the atlas and the occipital bone move as a single unit. Therefore hereinafter in the description of such movements the atlas and the occipital bone will be referred to as *the occipito-atloid unit* in order to stress that it is not only the atlas but also the cranium that partakes in such movements.

In the literature most interest has been focused on the atlo-axoid joint unit which was originally conceived as permitting

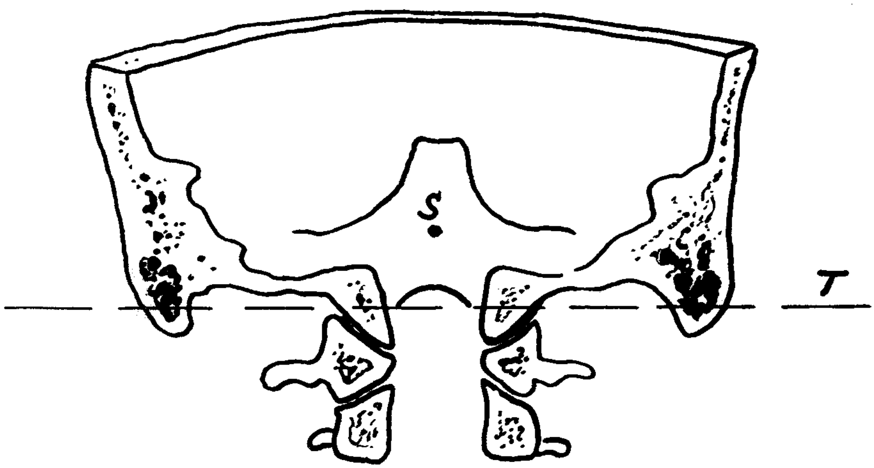


Fig. 7. After HENKE.

S indicates the point where the sagittal axis of the occipito-atloid joint unit passes through the clivus.
T indicates the transverse axis of the occipito-atloid joint unit.

rotation only. The now widely accepted view that this joint unit is a double-threaded screw joint was suggested by HENKE (1858) in his *Die Bewegung zwischen Atlas und Epistropheus.*

Because of the biconvexity of the intervertebral joint surfaces between the atlas and the epistropheus HENKE conceived the turning of the head as a screw movement, the atlas on movement from its midposition declining the anterior surface of one side and the posterior surface of the other side of the epistropheal intervertebral articular surfaces (see BROMAN & HJORTSJÖ pp. 117—118).

This view was criticized by HULTKRANTZ (1912) who found the profile of the articular surfaces of the atlas in sagittal sections could be either slightly concave or convex. According to HULTKRANTZ, the curvature was seldom so pronounced that its radius could be measured. He therefore concluded that the screw movement is not characteristic of turning of the head in all phases but probably only in the final phases of the movement.

The conception that the atlo-axoid joint unit is a uniaxial joint (WEBER, HENKE) has been criticized by HULTKRANTZ 1912, H. VIRCHOW 1928, R. FICK 1929, and BAKKE 1931 who demonstrated the co-occurrence of a transverse axis.

An assumption of MORRIS (1879) that the atlo-axoid joint unit is triaxial, thus the co-occurrence of a sagittal axis, appears to have been winning ground in recent years. Thus, HULTKRANTZ, BAKKE, DANKMEIJER & RETHMEIER (1943) and JACOBSON & ADLER (1953) have claimed that they could observe a slight degree of sideward movement on roentgen examinations.

FUNCTION OF THE LIGAMENTS

Of *the outer ligaments of the craniovertebral apparatus,* the dorsal ligaments are considered to inhibit flexion and the ventral to inhibit retroflexion.

The function of *the intraspinal, special ligaments* is more complicated and therefore requires a more detailed description of the role played by the ligaments in this apparatus.

MEMBRANA TECTORIA

According to HECKER this ligament inhibits retro- as well as anteflexion in the occipito-atloid joints by its laterally ascending bands.

Any accessory ligaments of the intervertebral joint capsules between the atlas and the epistropheus, Arnold's ligament, do not cross any joints and are not believed to have any significant function in the mechanism of the craniovertebral apparatus except to strengthen the capsules (HECKER).

THE CRUCIFORM LIGAMENT

With its transverse fibres, the ligamentum transversum atlantis, this ligament holds the dens epistrophei against the anterior arch of the atlas in the annulus osteofibrosus. According to R. FICK, rotation therefore occurs around the dens epistrophei like a wheel around its axle.

HECKER also expressed the view that the transverse ligament prevents vertical translation in the atlo-axoid joints. Thus the caput dentis would, according to him, behave like a button in a button hole.

The descending as well as the ascending fibres of the ligament including Gruber's ligament, have, in HECKER's opinion, no function other than to stabilise the transverse ligament.

THE ALAR LIGAMENTS

According to HENKE these ligaments are taut in the mid-position *i. e.,* when the head is facing forward. He described the possibility of rotation of the head as follows: the occipito-atloid unit gradually descends on rotation with gradual slackening of the alar ligaments, which thereby permit rotation until the occipito-atloid unit ceases to descend. Then the alar ligament on one or the other side tightens and inhibits rotation. FICK shares this view. According to this conception, on rotation of the occipito-atloid unit to the right, for example, the left alar ligament is drawn taut and prevents movement. R. FICK also added that this tightening of the alar ligament in the above example the left, leads to traction of the occipital condyle on that side. Therefore turning of the head to the right is associated with a lateroflexion of the cranium to the left.

The alar ligaments are also said to limit lateroflexion in the occipito-atloid joints (R. FICK, HECKER); by lateroflexion to the left, for example, tightening of the right alar ligament inhibits the movement.

Lauth's accessory ligament is believed to have no function other than to stabilise the alar ligaments (HECKER).

LIGAMENTUM APICIS DENTIS

According to HECKER, owing to the poor development of this ligament and its elastic consistence the ligament cannot be of any special functional significance.

SCOPE OF MOVEMENT OF THE OCCIPITO-ATLO-AXOID JOINTS AND FACTORS LIMITING MOVEMENTS

Data on the range of mobility of the craniovertebral joints given during the last few decades have been taken from the works of R. FICK and POIRIER & CHARPY. They give:

	R. FICK	POIRIER & CHARPY
Occipito-atloid joints		
Ante-retroflexion	50°	50°
Lateroflexion	30—40°	14—40°
Atlo-axoid joints		
Ante-retroflexion	insignificant	11°
Lateroflexion	0	4 mm
Rotation	60°	30—80°

Of factors limiting movement the ligaments have been discussed in the description of the function of the ligaments. The role of the muscles as a factor limiting movement will not be dwelt on here because it is of no relevant importance for the later discussion.

According to R. FICK skeletal contact limits the range of movement of the occipito-atloid joints, where contact occurs between the posterior edge of the occipital condyles and the posterior edge of the upper articular surfaces of the atlas on retroflexion.

Chapter III

AUTHOR'S INVESTIGATIONS

MECHANISM OF THE CRANIOVERTEBRAL JOINTS

As is apparent from the preceding sections, the conception of the mechanism of the craniovertebral joints has gradually emerged from details given by different authors.

As to the *occipito-atloid joints* there has, as pointed out earlier, been divergence of opinion on the mechanics of such a type of joint. Judging by observations made in the present investigation and by the work of HENKE and R. FICK, it may be regarded as established that the occipito-atloid joints as a unit is bi-axial, the axes crossing each other in different planes and permitting two types of movement, forward and backward bending and tilting to either side.

The *atlo-axoid joints* as a unit is regarded as a triaxial joint, since in addition to rotation and ante-retroflexion a certain lateroflexion has also been claimed on the basis of roentgenographic investigations (HULTKRANTZ, BAKKE, DANKMEIJER & RETHMEIER, JACOBSON & ADLER).

Turning of the atlas is said to be a screw movement (HENKE). Movement occurs around the dens like a wheel around an axle (R. FICK) and the axis, the vertical axis, therefore passes centrally through the annulus osteofibrosus and collum dentis (R. FICK).

R. FICK accepted the claim of HULTKRANTZ and H. VIRCHOW that they could roentgenographically demonstrate ante-retroflexion in the atlo-axoid joints. R. FICK states, however, that this bending was not compatible with the construction of atlo-axoid joints because the transverse ligament of the atlas should logically prevent forward bending and the anterior arch of the atlas backward bending. It appears that it has not yet been established how these movements can occur. Neither has the position of the transverse axis been determined.

If sideward tilting in the atlo-axoid joints is possible, the anatomic basis and mechanism of such movement have not been cleared up.

The purpose of the following investigation was to elucidate the mechanism of the atlo-axoid joints.

INVESTIGATION OF THE MECHANISM OF THE ATLO-AXOID JOINTS

Rotation in the atlo-axoid joints was studied on 5 anatomic preparations from autopsies (Nos. 24—28 in Table VII).

This investigation was carried out on anatomic preparations because it was necessary to study the movement relative to the epistropheus. Roentgen-examination or postmortem examinations would not have been suitable, because it would then not have been possible to prevent movement of the epistropheus. This point will be reverted to later (page 47).

Atlas-rotation was found to occur, as described by R. FICK, like a wheel around an axle, *i. e.* with the annulus osteofibrosus as the hub and the collum dentis as the axle.

It should be observed that both the dens and the annulus osteofibrosus occupy an eccentric medioanterior position in relation to the epistropheus and the atlas respectively. Therefore on rotation of the atlas its forwardly rotating condyle will project beyond the anterior circumference of the epistropheus.

In all these cases the path of movement of the condyles of the atlas was curved and thus in accordance with the description of HENKE.

The preparation from one subject (No. 28) a male, aged 35, showed normal neck-ligaments and ligament attachments. This preparation was used for investigation of the vertical movement of the condyles of the atlas on rotation in the atlo-axoid joints. The preparation was placed on a horizontal support resting on the corpus epistrophei, the spinal process and the transverse processes with a disk about 2 mm thick under each of the latter two. On maximal forward rotation the condyle of the atlas was found to occupy its highest position. It descended 2 mm on backward rotation to midposition and another 4 mm *i. e.*, a total of 6 mm, on further rotation to maximal backward position.

The condyle of the atlas thus on atlas rotation described a descending curve during movement from maximal anterior position to maximal posterior position.

On roentgen examination of the preparation from the side and in the position described above it was found that a tangent between the dorsal contours of caput dentis and corpus epistrophei showed a posterior inclination of only 5°.

Bending movement of the atlo-axoid joints was studied roentgenographically on a series consisting of 104 subjects with normal joints (52 males and 52 females). The material and technique are described on pages 63—70.

The mechanism of the bending movement of the atlo-axoid joint cannot be studied satisfactorily on anatomic preparations or post mortem because then skeletal or soft parts normally participating in the movement must be at least partly removed. Therefore roentgenography was considered the best method available for studying the mechanism of the craniovertebral joints during ante-retroflexion.

On *retroflexion* in the atlo-axoid joints the anterior arch of the atlas was usually shifted cranially relative to the dens. Fig. 8 gives a copy of superimposed roentgenograms of the atlas in maximal dorsoflexion and maximal anteflexion respectively, showing the shift of the anterior arch along the dens. This displacement was measured with a millimeter-scale at right angles to the tangent of the posterior outline of the caput dentis and corpus epistrophei (Fig. 9). The displacement was measured to the nearest mm. After correction for roentgenographic enlargement the average displacement was found to be 1.4 mm (1.7 mm for females and 1.1 mm for males).

In 23 cases no such shift was observed, *i. e.*, in the event of

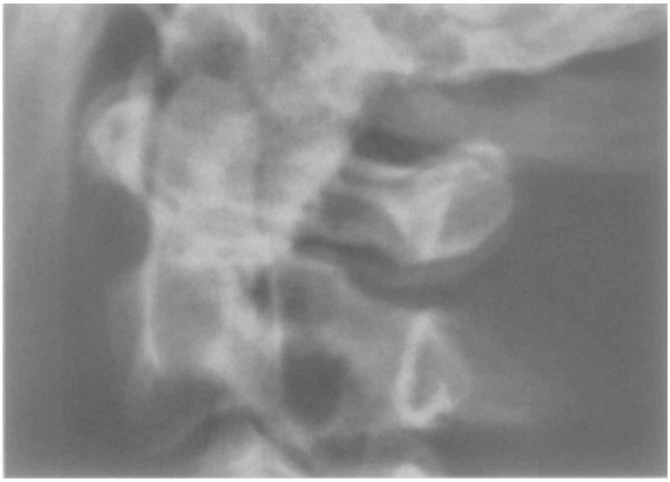


Fig. 8.

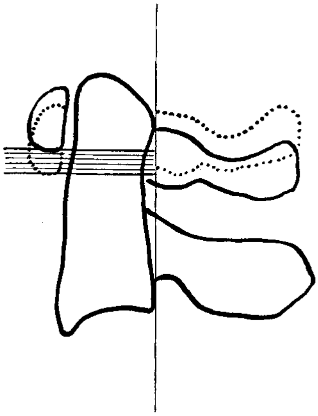


Fig. 9.

Fig. 10.

such shift it was less than 0.5 mm. Only in 4 cases did the displacement exceed 4 mm (3 mm corrected value).

On *anteflexion* a cranial gaping was usually noted in the anterior odontoid joint (Fig. 10). This change in position was often distinct but it was not possible to measure the angle because of the smallness of the movement, the combined shift of the anterior arch of the atlas and the curved surfaces of the dens and of the arch of the atlas.

Sagittal translation was studied in anatomic preparations and roentgenographically. This movement was not studied at autopsies because visual inspection of the joints would not have been possible.

Transverse translation was studied on preparations of the cranio-vertebral joints. The investigation could not be extended to include post mortem examinations or roentgen examinations because on the former visual inspection of the joints would not be possible and because in the latter co-movement of the epistropheus cannot be excluded.

Vertical translation was studied at autopsy and on a complete preparation of the cranio-vertebral joints. This permitted investigation of translation in relation to the apex dentis. Roentgenologic investigation of vertical translation involves technical difficulties and further verification of a minimal vertical translation was not considered of importance for the later studies.

Horizontal translation, *i. e.*, along the transverse and sagittal axes, could not be produced in the atlo-axoid joints in any of the above-mentioned 5 preparations. No translation along the sagittal axis was observed in the 104 roentgenographic examinations of the movements of the neck.

A slight vertical translation was observed at 19 autopsies (Table I, page 39) and in the above-mentioned complete preparation of the cranio-vertebral joints. This was noted, however, only when the cranium was in mid-position. In 4 cases in which it was measured, it never exceeded 1 mm (Table I).

DISCUSSION

Already on visual inspection of the above-mentioned preparations of the cranio-vertebral joints it was obvious that on rotation of the atlo-axoid joints the condyles of the atlas described a vertically arcuated path, as pointed out by HENKE. In investigations on sagittal sections through the intervertebral joints HULTKRANTZ questioned the occurrence of such movement. Many objections can, however, be raised against HULTKRANTZ's investigations, *e. g.* a circular path of movement is not reproduced in sections forming a tangent to the path of movement. In Fig. 11 the path of movement of the condyles of the atlas, as seen from above, are given as circles in relation to the epistropheus. Sagittal tangents of these circles show the

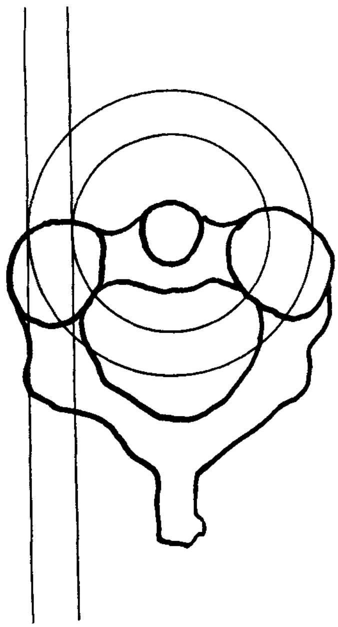


Fig. 11.

course of sagittal sections through the intervertebral joints and how they thereby deviate from the path of movement illustrated by the circles.

Whether rotation in the atlo-axoid joints includes a screw movement in the sense of HENKE depends on the direction of the axis of movement relative to the longitudinal axis of the body. In the above described investigation the direction of the longitudinal axis of the body was assumed to be perpendicular to the horizontal support of the epistropheus. Then the backwardly rotating condyle of the atlas described a descending curve and the forwardly rotating condyle an ascending curve, *i. e.* the axis of the rotatory atlas movement had a backwardly inclined position relative to the imaginary longitudinal axis of the body. Rotation of the atlas must under such circumstances be described as a movement combined with lateral deviation of the longitudinal axis of the atlas. If, however, the axes of the body and the rotatory atlas movement coincide, as supposed by HENKE, the rotation of the atlas must be described as including a screw movement. If it be assumed that the axis of the rotatory movement is inclined forward relative to the longitudinal axis of the body, rotation of the atlas would again be combined with a lateral deviation of the longitudinal axis of the atlas, but now in the opposite direction, because the condyles of the atlas would now describe a descending curve on anterior rotation and an ascending curve on backward rotation.

It is not intended to question the occurrence of a screw movement in the sense of the term used by HENKE but to stress the importance of judging rotational or screw movement relative to the long axis of the body. It should thus be recollected that the convex intervertebral articular surfaces facing one another in the atlo-axoid joints may allow a type of movement other than screw movement only. If the joints occupy a horizontal position and their rotatory axis thus coincides with the longitudinal axis of the body, rotation will involve screw movement, but if the joints occupy a more or less forwardly or backwardly inclined position, movement of the atlas will be rotational rocking.

Analysis of the mechanism of the atlo-axoid joints during bending movements must be made relative to the fixation of the atlas in the horizontal plane because the annulus osteofibrosus surrounds the collum dentis (R. FICK, HECKER).

During anteflexion the range of bending of the atlas is usually increased by a cranial gaping in the anterior odontoid joint (Fig. 10). This gaping suggests a certain yieldability of the cranial edge of the transverse ligament, a point which will be discussed later in the investigation of ligamental function (page 43).

Retroflexion would be prevented if the anterior surface of the dens epistrophei were vertical. But it is not. In vertical direction it curves more or less backward as is shown in Fig. 12 representing the outlines of 15 lateral roentgenograms of

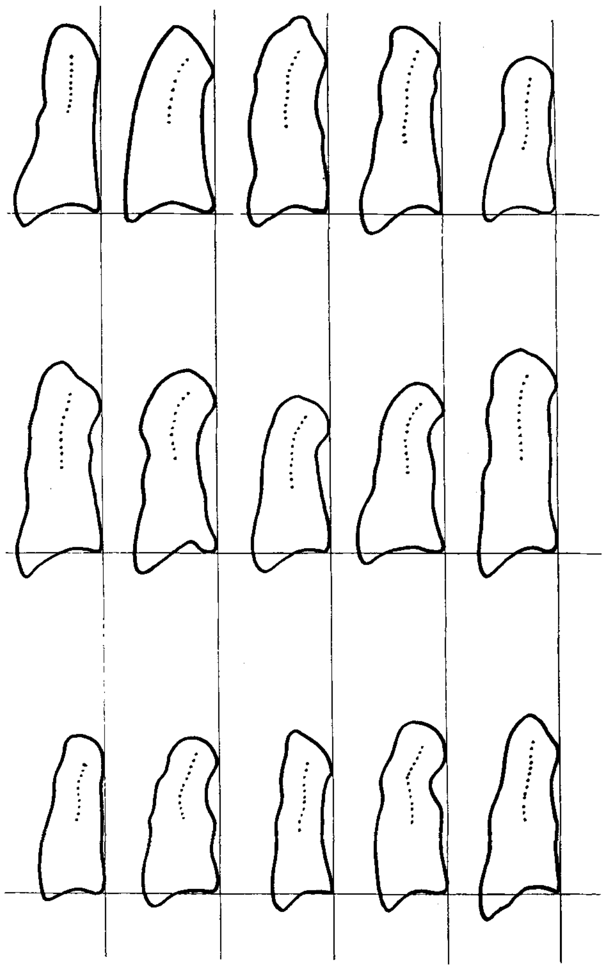


Fig. 12.

the dens. This permits to some amount the anterior arch of the atlas to glide along the dens notwithstanding the fixation of dens in the annulus osteofibrosus thus permitting some dorsoflexion in the atlo-axoid joints.

Although it is probable that the bending in the atlo-axoid joints can be more or less pronounced of the type anteflexion or retroflexion, the average position of the axis of movement owing to fixation of the collum dentis in the annulus osteofibrosus must be regarded as approximately determined to extend through the center of this ring but to be located further ventrally during anteflexion and further dorsally during retroflexion.

No tilting in the atlo-axoid joints was observed. There is no possibility for such a movement in the form of rotation, because the intervertebral joint surfaces are perpendicular to the imagined motion. Tilting by translation is prevented by fixation of the collum dentis in the annulus osteofibrosus.

With the occipito-atloid unit in mid-position slight vertical translation was observed. This translation is, however, insignificant. Normally this translation is probably prevented by the weight of the head and by muscle tonus. At any rate it cannot be produced by muscle activity and therefore is reason to assume that it does not occur in vivo.

Sagittal and transverse translation are not possible because in the horizontal plane the atlas and the epistropheus are firmly fixed to each other.

SUMMARY

In accordance with what was stated earlier the following movements are possible in the cranio-vertebral joints:

Occipito-atloid joints	1)	ante-retroflexion	(bending)
	2)	lateroflexion	(tilting)
Atlo-axoid joints	1)	ante-retroflexion	(bending)
	2)	rotation	(turning)

The craniovertebral joints thus permit three types of movement, ante-retroflexion or bending, lateroflexion or tilting, and rotation or turning.

These three types of movement are made possible by 4 axes,

a sagittal axis in the occipito-atloid joints, a vertical axis in the atlo-axoid joints, and a transverse axis in each craniovertebral joint unit. Bending thus involves both craniovertebral joint units.

With their three possibilities of movement, the craniovertebral joints function like a ball and socket joint.

FACTORS LIMITING THE RANGE OF MOVEMENT OF THE CRANIOVERTEBRAL JOINTS

As pointed out in earlier sections, data available on the anatomy and function of the intraspinal ligaments of the craniovertebral joints are contradictory and vague. Suffice it here to point out that the alar ligaments are described as tight ligaments and that the membrana tectoria is believed to limit the ranges of both anteflexion and retroflexion in the occipito-atloid joints. If this were true, however, it would imply that the craniovertebral joints would be completely fixed. It was therefore considered desirable to investigate the factors limiting movement of the craniovertebral joints.

Autopsy studies were carried out on a material consisting of 19 cases (Table I, page 39) and 5 anatomic preparations of the craniovertebral joints (Table VII, Nos. 24—28, page 106).

The calotte, brain and medulla oblongata were removed. After the dura mater spinalis likewise had been removed the special ligaments were available for examination in situ via foramen occipitale magnum.

Most of the examinations were carried out to confirm or disprove personal assumptions and earlier statements by others. In view of the different purposes dissection was carried out in different ways, and therefore they are described separately in appropriate sections.

It would have been desirable in the subsequent sections to deal with the factors limiting each type of movement of every joint separately, but this is only possible for ante-retroflexion. It was found that the other two alternatives, lateroflexion and rotation, are combined with one another. It was therefore considered advisable to study each ligament for any possibility of its inhibiting motion, and afterwards study any interplay between the ligaments.

TABLE I.

Autopsy studies.

Case No.	Age in years	Sex	Alternative A 1	Alternative A 2	Alternative A 3	Alternative A 4	Alternative B 1	Alternative B 2	Alternative B 3	Alternative B 4	Alt. C 5	Causa mortis
I	20	M				0–1				6–7	8	Leukaemia
II	47	M			39	0–1			39	0–1	4	Uraemia
III	45	F			43	0–1			43		4	Periarteritis nodosa
IV	22	M		10		0–1				4	4	Mors violenta
V	16	F		10	54				54	2–3	4–5	Poliomyelitis
VI	18	M	22	6	51				51	2–3	3–4	Cancer oesophagi
VII	61	M	18	12	53				52	1–2	2–3	Infarctus cordis
VIII	55	M	28	14							2–3	Anemia perniciosa
IX	34	F	41	12	61		45	12	63			Diabetes mellitus
X	82	F	36	10	55				55			Cholecystitis
XI	64	M	36	8	65		36	8	68			Vitium organicum cordis
XII	48	F	25	12	41		31	12	41		3–4	Tumor cerebri
XIII	56	F	33	6	47		35	9	48			Vitium organicum cordis
XIV	60	F	36	16	43		37	23	47		4–5	Intoxicatio
XV	56	F	36	13	44		35	14	45		4–5	Diabetes mellitus
XVI	19	M	36	16	60		35	16	59	3–4	6–7	Elephantiasis
XVII	36	F	24	19	48		24	19	48	1–2	4	Uraemia
XVIII	41	F	28	12	49		36	12	46	1–2	2	Tuberculosis pulmonum
XIX	25	M	18	14	24		22	18	24		6	Leukaemia

Alternativ A: Ligaments in situ.
Alternativ B: Dura and membrana tectoria removed.
Alternativ C: Dura and membrana tectoria removed, ligamentum transversum atlantis divided.

1. Ante-retroflexion (°).
2. Lateroflexion (°).
3. Rotation (°).
4. Vertical translation (mm).
5. Dislocation forwards or diastasis in anterior odontoid joint (mm).

MEMBRANA TECTORIA

OCCIPITO-ATLOID JOINTS

On *anteflexion in the occipito-atloid joints* the anterior portions of the base of the skull descend (dotted in Fig. 13) including the attachment of the membrana tectoria on the clivus.

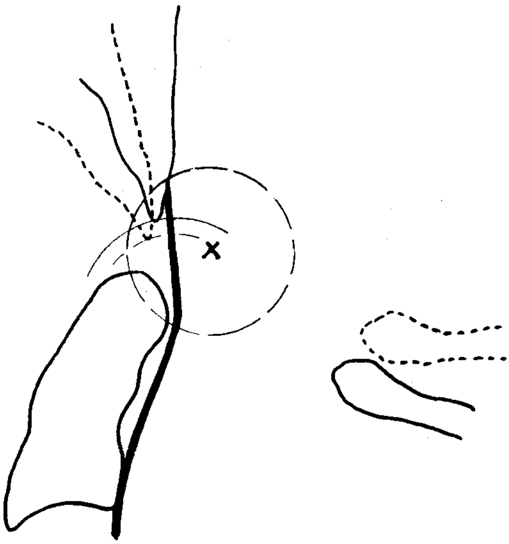


Fig. 13.

The attachment and the point where the membrana tectoria rides over caput dentis approach one another, whereby the ligament becomes slack and consequently cannot check anteflexion in the occipito-atloid joints.

COMMENTS

The course of the other special ligaments closely resembles that of the membrana tectoria, in parallel layers between the caput dentis and the base of the skull (Figs. 5—6). Ligaments checking anteflexion in the occipito-atloid joints are consequently not to be found among the special ligaments.

In these investigations the anterior margin of foramen occipitale magnum was found to contact the caput dentis via an interposed bursa, which, since it was not found to be described in the literature before, has been called *bursa apicis dentis* here. The wall of the bursa was sometimes so well developed that it gave the impression of a further ligament. In 2 cases

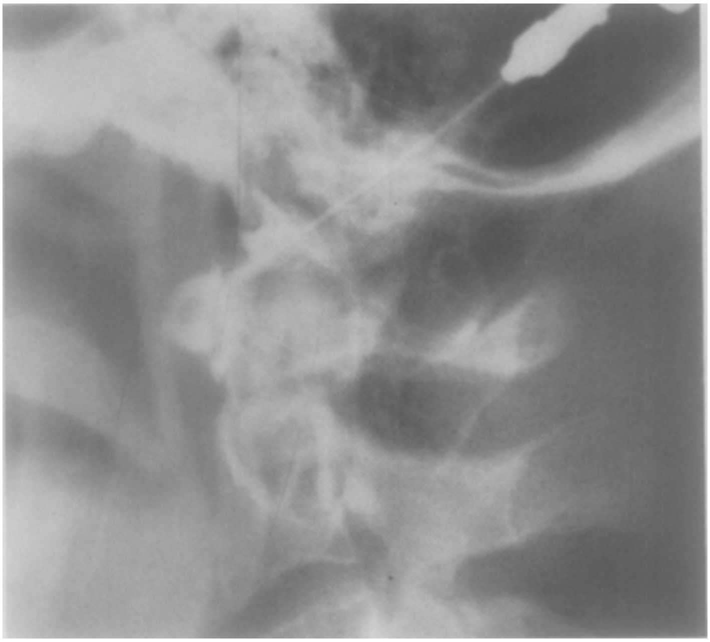


Fig. 14.

its extent and relation to the surroundings was examined roentgenologically by injecting contrast medium (umbradil) into the bursa (Fig. 14). It was found to communicate with the odontoid joints.

On retroflexion in the occipito-atloid joints the attachment of the membrana tectoria travels away from the point where the membrana tectoria rides over the caput dentis. The ligament is thereby tightened and then checks retroflexion in the occipito-atloid joints.

ATLO-AXOID JOINTS

As mentioned, anteflexion in the occipito-atloid joints is checked by skeletal contact between the anterior margin of

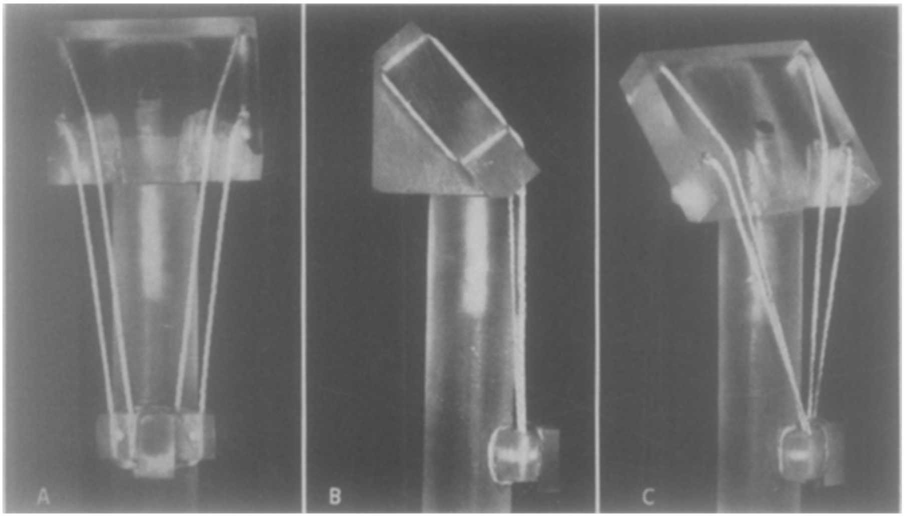


Fig. 15.

The model illustrates the slightly divergent fibres of the membrana tectoria between corpus epistrophei (lowermost) and the clivus (uppermost).
The model contains a central axle about which the clivus part can rotate.
A. Model in midposition, seen from behind.
B. Model in midposition, seen from the side.
C. The clivus part rotated 45° before the silk threads representing the ligamentfibres inhibit further rotation.

the foramen occipitale magnum and the caput dentis. During this movement the membrana tectoria becomes slack. On further anteflexion of the head the anterior margin of the foramen occipitale magnum shifts forwardly, downwardly over the caput dentis. This movement is only possible by *anteflexion in the atlo-axoid joints.* The membrana tectoria is thereby tightened with the caput dentis as a fulcrum and in turn checks anteflexion in the atlo-axoid joints.

If the membrana tectoria is tightened beforehand by retroflexion in the occipito-atloid joints, it would inhibit *retroflexion in the atlo-axoid joints* by exerting a counter-pull on the outer ligaments of the craniovertebral joints.

No observations were made to suggest that the membrana tectoria inhibits rotation in the atlo-axoid joints. The funnel-shaped form of the membrana tectoria with a broad semi-circular attachment on the basis cranii and the relatively narrow origin on the epistropheus does not suggest any checking effect of the rotation. The torsion of the membrana tectoria necessary to check rotation would be far in excess of the range of rotation.

This was confirmed in model experiments (Fig. 15). The ligaments given in the model are tight in midposition (Fig. 15 A—B). This model permitted rotation through 45° in either direction (Fig. 15 C). Therefore it appears that the membrana tectoria has no checking effect on rotation.

LIGAMENTUM CRUCIFORME

The ascending as well as the descending bands of the ligamentum cruciforme were not found to have any checking effect on motion. The *ascending band* was often found to be so thin and slack that it gave the impression of a bursal wall, which also appears to be its main function. The *descending band* showed no inhibition of vertical translation of the occipito-atloid unit of up to 6—7 mm (Table I), *i. e.* until the dens appeared to luxate out of the annulus osteofibrosus, for which reason this ligament does not appear to have any checking effect on movement.

The investigation did not include a study of the accessory *Gruber-ligament.*

The relatively short vertical diameter of the attachments of the *transverse ligament,* its relatively long vertical diameter of the central part and the almost transverse course of the cranial fibres (Fig. 16) explain why the ligament has a certain yieldability in its cranial portion permitting anteflexion in the atlo-axoid joints.

This ligament appears to have no checking effect on normal movement.

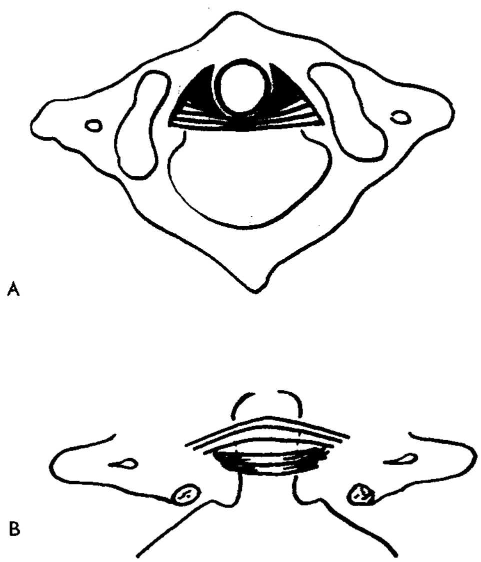


Fig. 16.

A. Diagram illustrating course of the fibres of the ligamentum transversum atlantis, seen from above. The cranial fibres run transversely, the basal fibres semicircularly. The medial portion is vertical, the lateral portions almost horizontal.

B. Diagram illustrating course of the fibres of the ligamentum transversum atlantis, seen from behind. The vertical diameter is largest in the medial portion, whereby the cranial fibres, which run almost transversely, are able to yield somewhat ventrodorsally and thereby permit anteflexion in the atlo-axoid joints.

HECKER described the transverse ligament as inhibiting vertical translation in its capacity as part of the annulus osteofibrosus. The caput dentis then being said to act "like a button in a button-hole". No such function was demonstrable.

On rotation in the atlo-axoid joints the caput dentis usually shifts laterally, which is made possible by the cranial part of the transverse ligament leaving the caput dentis without lateral contacts (Fig. 16). If it also be recollected that the cranial part of the transverse ligament, as mentioned earlier, has a sagittal yieldability there appears to be reason to make a distinction between the collum portion and the caput portion of the transverse ligament. When the term annulus osteofibrosus occurs in this book it is from a functional point of view to be understood as referring only to the ring formed by the anterior arch of the atlas and the collum portion of the transverse ligament.

ODONTOID LIGAMENTS

ALAR LIGAMENTS

The alar ligaments are usually described as being tight when in midposition (HENKE, R. FICK, RAUBER & KOPSCH, SPALTEHOLZ).

In all of the autopsies these ligaments were found to be about the thickness of an ordinary lead pencil, rounded, and slack in midposition. Fig. 20 shows stereoscopically the appearence of the alar ligaments and their course in midposition.

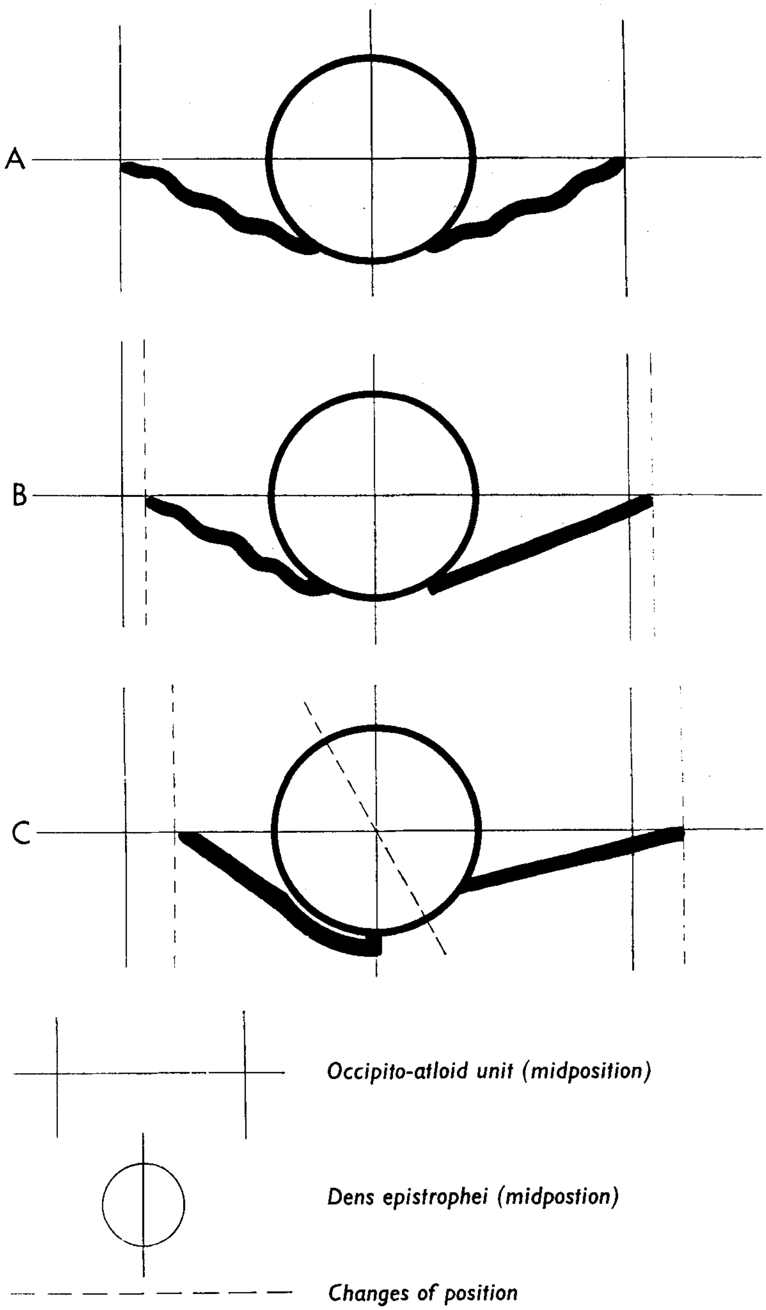
FUNCTION OF THE ALAR LIGAMENTS ON LATEROFLEXION

On lateroflexion of the head, *e. g.* to the right, the left alar ligament tightens up. The dorsal part of the caput dentis should, according to the classical conception, then offer resistance to inhibit further movement.

One condition which must be fulfilled for this to be possible is that the epistropheus is fixed. But it is not. The pull exerted by the alar ligament on the posterior surface of the caput dentis mainly in lateroventral direction produces a rotation of the epistropheus, the anterior surface of which rotates in the direction the head is tilted.

In this combined movement the function of the ligaments is best understood if explained step by step.

1) In the starting position, *i. e.* midposition, the alar ligaments are slack (Fig. 17 A).
2) On moderate lateroflexion, *e. g.* to the left, the right alar ligament tightens up (Fig. 17 B).


A
B
C
Occipito-atloid unit (midposition)
Dens epistrophei (midpostion)
Changes of position

3) On extreme lateroflexion, the dens rotates, whereby also the left alar ligament is tightened up (Fig. 17 C).

Not until both alar ligaments are tight do they inhibit movement.

Extreme lateroflexion thus results in the epistropheus rotating in the same direction as the head is tilted, *i. e.* lateroflexion of the cranium to the left results in rotation of the epistropheus to the left.

FUNCTION OF THE ALAR LIGAMENTS ON ROTATION

What was said about the limitation of lateroflexion, namely that the epistropheus is not a fixed body, also applies here, for which reason the force transmitted via the alar ligaments results in a movement of the epistropheus. What really happens is as follows; for simplicity, the body or the epistropheus is supposed to rotate relative to a fixed head:

1) On moderate rotation, *e. g.* to the left, the left alar ligament tightens up (Fig. 18 B).
2) On extreme rotation the left alar ligament is shortened by winding around the dens epistrophei (Fig. 18 C).
3) The left occipital condyle approaches the dens, whereby lateroflexion occurs to the left in the occipito-atloid joints and the right alar ligament tightens up (Fig. 18 C).

Comparison of the final results in Figs. 17 and 18 show that the final positions are identical on rotation and on lateroflexion in the craniovertebral joints, thus lateroflexion to the left in the occipito-atloid joints is accompanied by rotation of the epistropheus with its anterior surface to the left — on rotation of the epistropheus to the left, there occurs a lateroflexion in the occipito-atloid joints to the left.

In both cases there occurs a rotation to the right in the atlo-axoid joints, and the same final picture is seen as in the former two, if the occipito-atloid unit rotates to the right, as shown in Figs. 19 C and 21.

The accessory *Lauth's ligament* were not found to have any special checking effect.

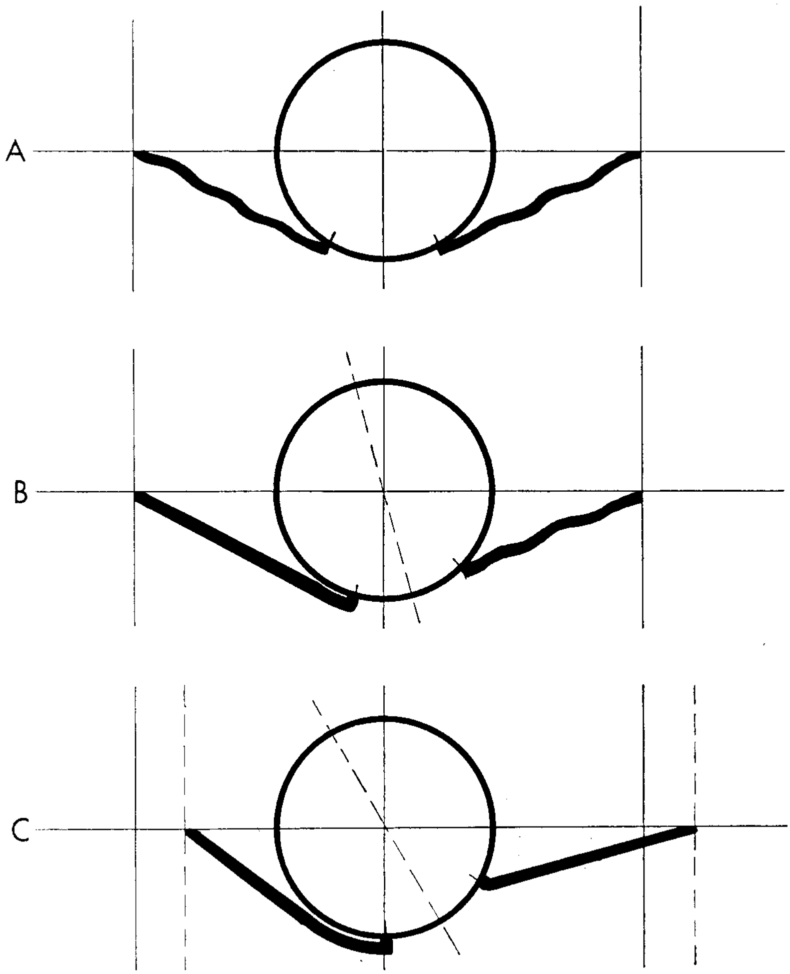


Fig. 18.

LIGAMENTUM APICIS DENTIS

The ligamentum apicis dentis has been described by HECKER as being of no functional importance. Neither in the present investigation was any checking function of this ligament observed.

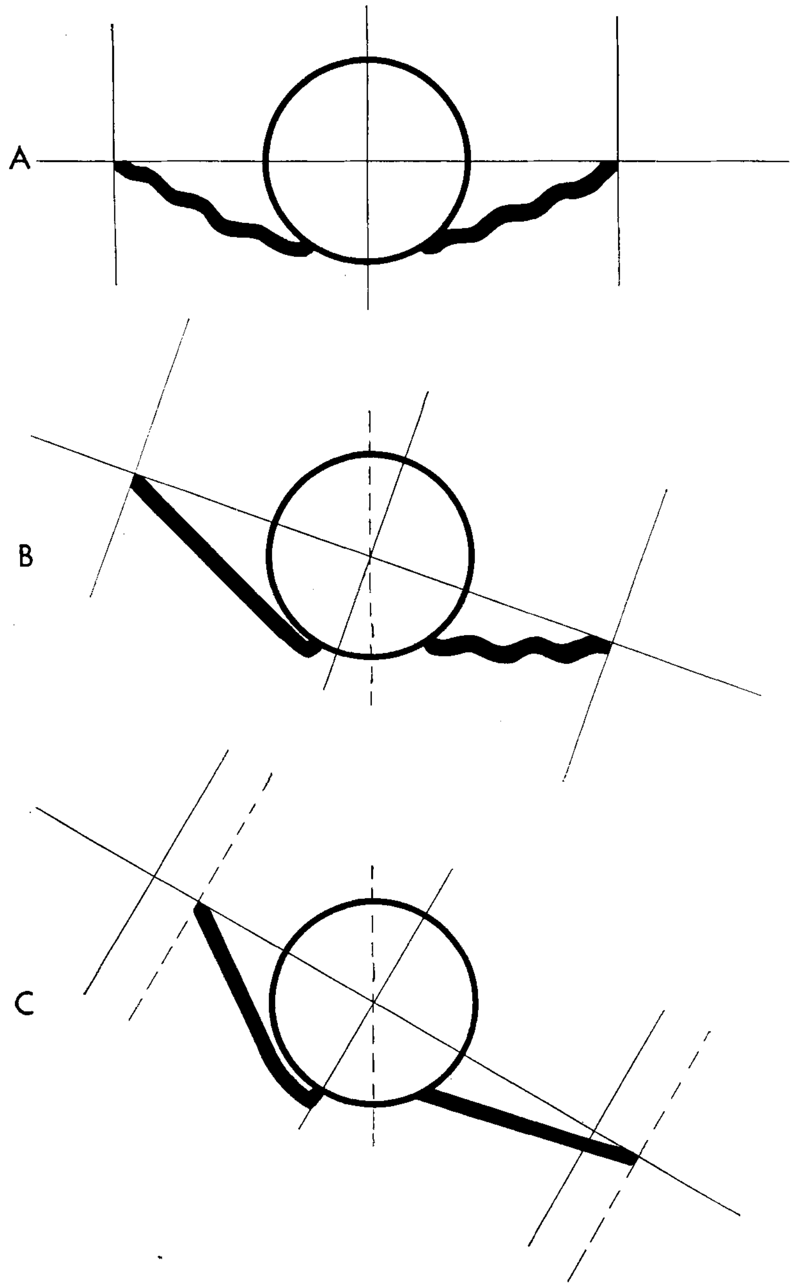


Fig. 19.

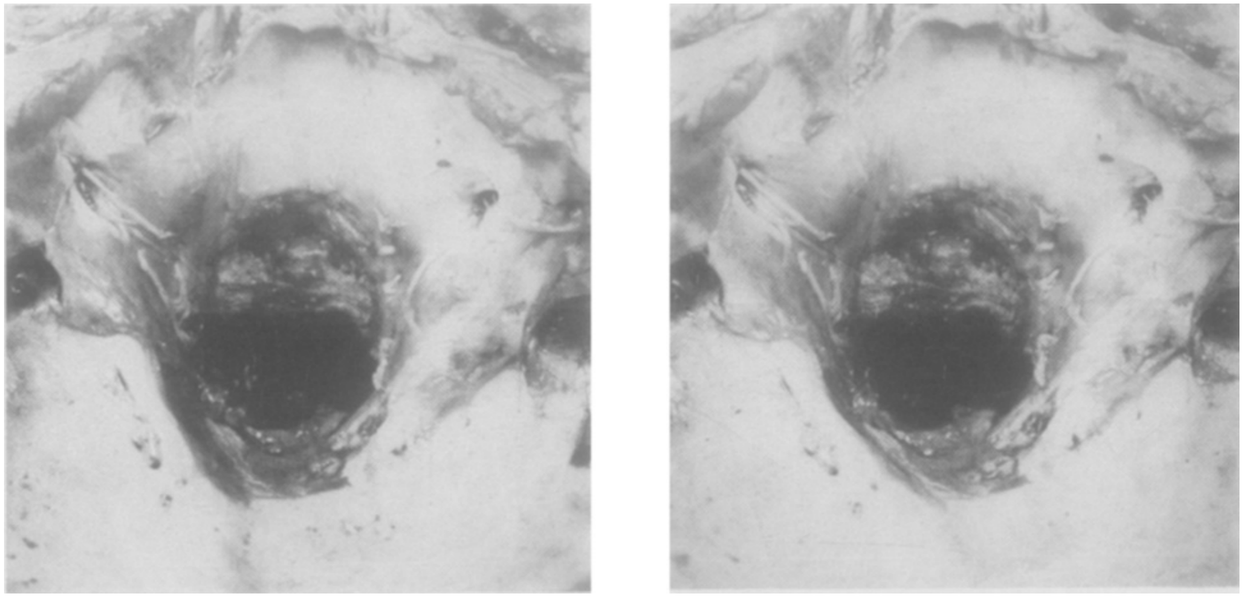


Fig. 20.

Stereoscopic views of foramen occipitale magnum, seen from above. The dura, membrana tectoria and ligamentum cruciforme are removed. The apex dentis and the coarse, slack alar ligaments from the dorsolateral surfaces of the caput dentis are seen anteriorly.

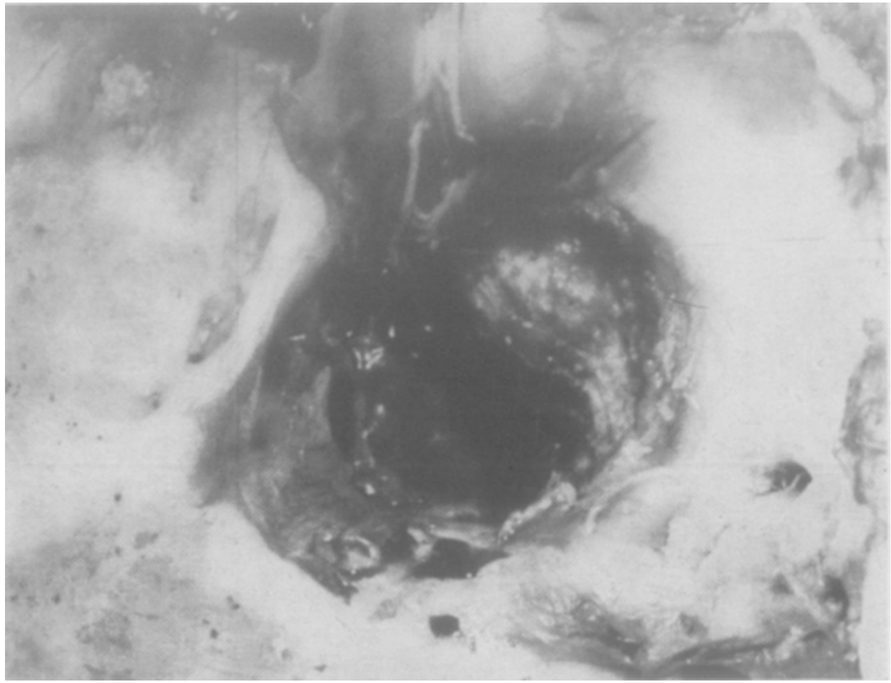


Fig. 21.

View showing how the left alar ligament is wound round the dens and thereby shortened, while the right alar ligament is tightened and exerting a counterpull, which inhibits further rotation of the cranium. The upper margin of the transverse ligament passes behind the dens and underneath the alar ligaments.

SUMMARY

The main checking functions of the special intraspinal craniovertebral ligaments may be summarized as follows:

I. *Membrana tectoria*
   1) checks retroflexion in the occipito-atloid joints,
   2) checks anteflexion in the atlo-axoid joints, and
   3) contributes to limitation of retroflexion in the atlo-axoid joints by exerting a counter-pull on the outer craniovertebral ligaments.

II. *Ligamentum cruciforme*
   does not check normal movement.

III. *The odontoid ligaments*
   Only the alar ligaments have any checking function. With the head in midposition they are slack, but together they check movement
   1) when rotation is extreme, and
   2) when lateroflexion is extreme.

The investigation also showed that anteflexion in the occipito-atloid joints is inhibited by skeletal contact between the anterior margin of the foramen occipitale magnum and the dens via an interposed bursa. It is suggested that this bursa be called *bursa apicis dentis*.

If we now apply the functions of the ligaments to the types of movement of the craniovertebral joints, the results can be summarized as follows:

Occipito-atloid joints
anteflexion is checked by skeletal contact,
retroflexion is checked by membrana tectoria,
lateroflexion is checked by the alar ligaments.

Atlo-axoid joints
anteflexion is checked by membrana tectoria,
retroflexion is checked by the outer ligaments with membrana tectoria exerting a counter-pull,
rotation is checked by the alar ligaments.

INVESTIGATION OF A POSSIBLE FUNCTIONAL INTERPLAY BETWEEN THE LIGAMENTS OF THE OCCIPITO-ATLO-AXOID JOINTS

As shown earlier (see page 52) the internal special ligaments of the craniovertebral apparatus are of functional importance in the occipito-atloid as well as the atlo-axoid joints. Since they run in parallel layers between the epistropheus and the occipito-atloid unit one might imagine functional interplay between them. This possibility was studied in autopsy cases accounted for in Table I on page 39.

ANTE-RETROFLEXION

The investigation was carried out at post-mortem examination of 3 males and 7 females aged 19—64 years.

After removal of the calotte and the brain a steel pin 2 mm in diameter and about 20 cm long was driven through the apex dentis into the collum of the dens. Movements of the cranium were judged relative to this pin. By its fixation in the epistropheus the pin represented the stationary body in relation to which movement was estimated. Ante-retroflexion of the cranium was registered on a protractor in the sagittal plane with the protractor resting posteriorly and anteriorly on the edges of the skull bones. The protractor was adjusted and read relative to the steel pin on maximal ante- and retroflexion (Fig. 22).

In these examinations use was made of a protractor with a large radius (15 cm) in order to limite measuring errors. Since each measurement required adjustment and reading a measuring error of $\pm 1^\circ$ cannot be avoided.

The difference between the range of ante-retroflexion before

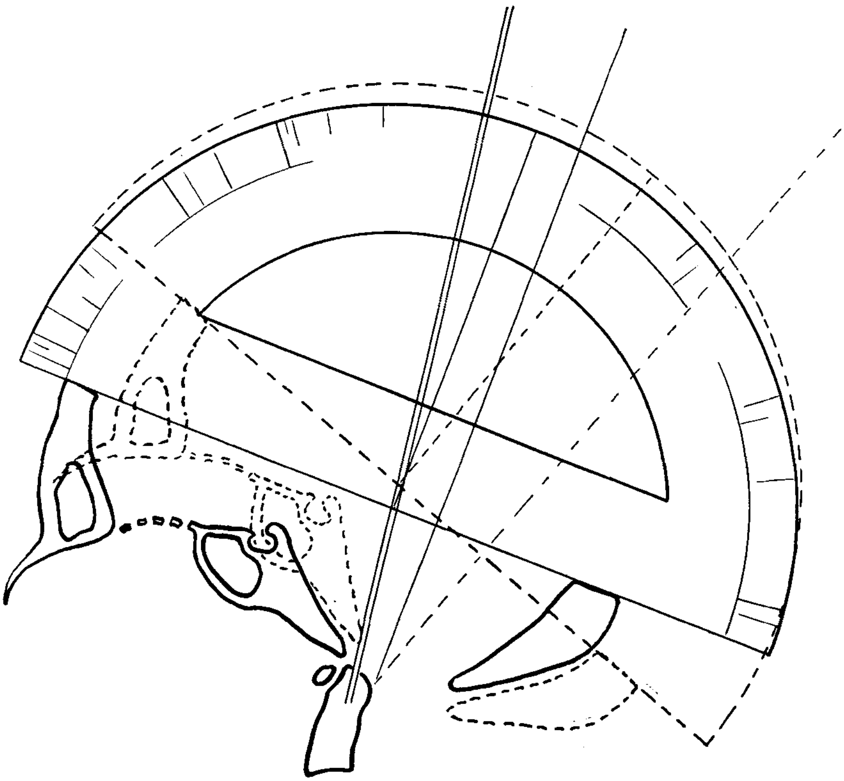


Fig. 22.

Measurement of the total ante-retroflexion of the craniovertebral joints *post mortem.* The centre of the protractor is set in relation to the steel pin and read with cranium in maximum anteflexion (uninterrupted line) and retroflexion (interrupted line). The difference between the readings is a measure of total ante-retroflexion.

TABLE II

Case No.	Age in years	Sex	Ante-retroflexion (°)		Lateroflexion (°)		Rotation (°)		Translation (mm) Vertical		Translation (mm) Sagittal
			A	B	A	B	A	B	A	B	C
I	20	M							0–1	6–7	8
II	47	M					37	37	0–1	0–1	4
III	45	F					41	41	0–1		4
IV	22	M							0–1	4	4
V	16	F					52	52		2–3	4–5
VI	18	M					49	49		2–3	3–4
VII	61	M					51	50 (−1)		1–2	2–3
VIII	55	M									2–3
IX	34	F	41	45 (+4)	12	12	59	61 (+2)			
X	82	F					53	53			
XI	64	M	36	36	8	8	63	67 (+4)			
XII	48	F	25	31 (+6)	12	12	39	39			3–4
XIII	56	F	33	35 (+2)	6	9 (+3)	45	46 (+1)			
XIV	60	F	36	37 (+1)	16	23 (+7)	41	45 (+4)			4–5
XV	56	F	36	35 (−1)	13	14 (+1)	42	43 (+1)			4–5
XVI	19	M	36	35 (−1)	16	16	58	57 (−1)		3–4	6–7
XVII	36	F	24	24	19	19	46	46		1–2	4
XVIII	41	F	28	36 (+8)	12	12	47	44 (−3)		1–2	2
XIX	25	M	18	22 (+4)	14	18 (+4)	22	22			6
Number of measurements			10		10		16		4	9	15
Mean values			31.3	33.6	12.8	14.3	46.6	47.0	0–1	2.7	4.3
Mean age in years			43.9		43.9		48.1		33.5	38.0	42.1

A: Ligaments in situ.
B: Dura and membrana tectoria removed.
C: Dura and membrana tectoria removed, transverse ligament divided.

and after removal of the membrana tectoria was in the ten experiments —1, —1, 0, 0, +1, +2, +4, +4, +6, and +8° (Table II), that is an average increase of 2.3°.

DISCUSSION

The difference found lay within the limits of the error of measurement in 5 cases. In the remaining 5 removal of membrana tectoria increased the average range of ante-retroflexion by 5°.

After removal of membrana tectoria the range of ante-retroflexion is sometimes slightly increased until limited by the alar ligaments. If the alar ligaments are also divided the occipito-atloid joints are no longer controlled directly by ligaments and conditions therefore provided for luxation of the caput.

Ante-retroflexion is thus limited by the membrana tectoria but to some extent by the alar ligaments. This checking effect of the alar ligaments, however, appears to vary from one case to another.

LATEROFLEXION

Measurement of the total lateroflexion before and after removal of the membrana tectoria were made in the same way and by the same technique and on the same material. The results showed that in 6 cases removal of the membrana tectoria produced no change in the range of mobility, in one case a change within the limits of the error of measurement and in 3 cases an increase by + 3, + 4, and + 7° (Table II).

DISCUSSION

Understanding of this to a certain extent surprising result will be easier if the physiological slackness of the alar ligaments and the individually varying angle between them be borne in mind and on the other hand that the laterally ascending bands of the membrana tectoria run a course analogous to that of the alar ligaments. In those cases in which the alar ligaments were more or less horizontal or in which they are markedly slack in midposition, it is possible that they might permit wide play for lateroflexion and that the laterally ascending bands of the membrana tectoria begin to function earlier than the alar ligaments. This produces rotation of the

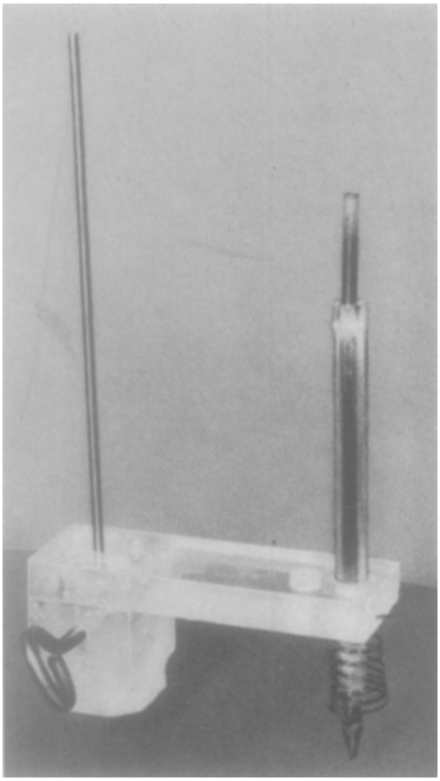


Fig. 23.

epistropheus, a rotation which is limited by the alar ligaments. Lateroflexion is then limited by its also being a rotational movement. The occasionally increased range of lateroflexion after removal of the membrana tectoria may thus be explained as retarded function of the alar ligaments.

ROTATION

Range of rotation before and after removal of the membrana tectoria was studied at 16 autopsies, 6 males and 10 females aged 16—84 (Table II).

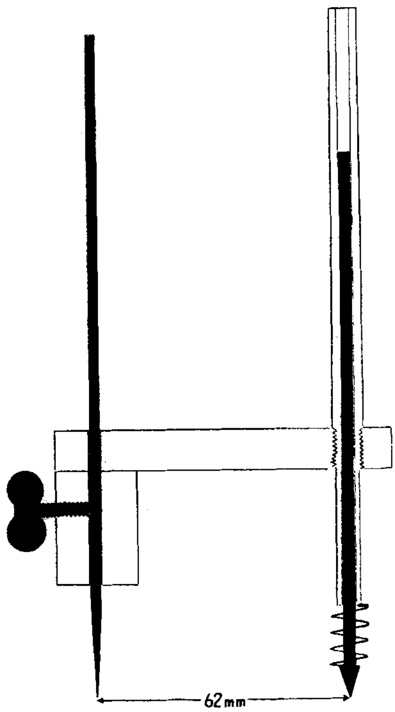


Fig. 24.

A pen parallel to the above mentioned steel pin was fastened to the latter by means of a plastic block (Fig. 23). The distance between the tip of the pin and the tip of the pen was 62 mm. The pen could move in its longitudinal direction but was fixed in all other directions (Fig. 24). All turning movements were registered by the pen on a plate resting on the posterior clinoid processes and the temporal bones (Fig. 25).

In 8 cases the measurements noted were the same before and after removal of the membrana tectoria. Differences were observed in 8 cases, —3, —1, —1, +1, +1, +2, +4, and +4° (Table II).

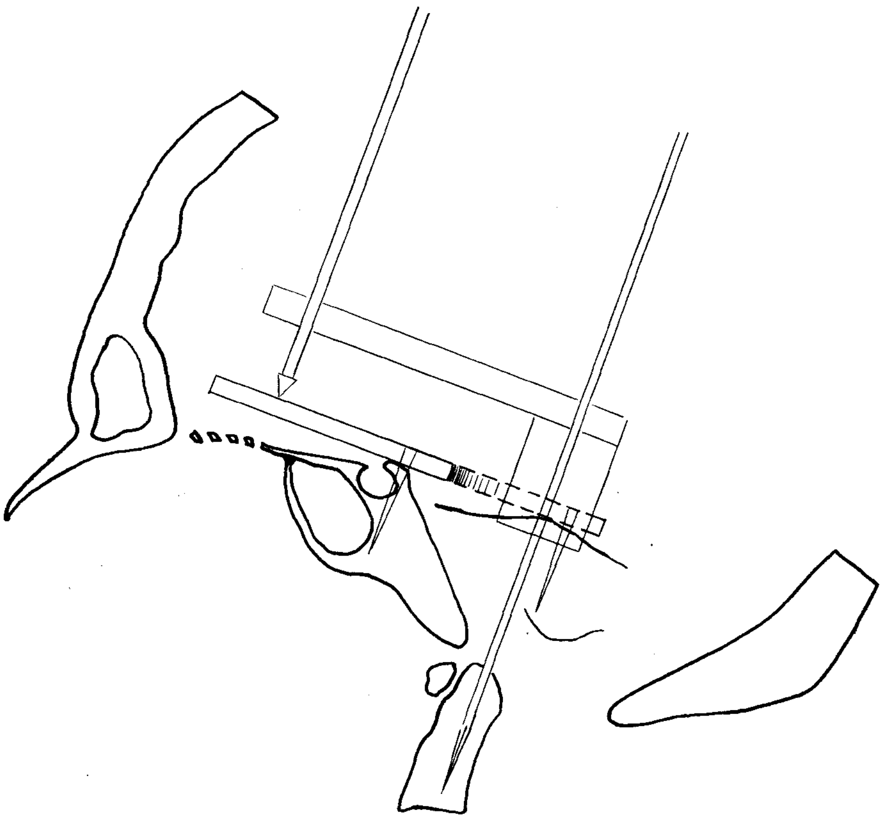


Fig. 25.

DISCUSSION

In view of the relatively short distance between the steel pin and the recording pen the measuring method must be regarded as fairly coarse. The differences recorded were probably due to errors of measurement.

The investigation thus supported the conclusion that the alar ligaments are mainly responsible for the limitation of rotation of the atlo-axoid joints.

VERTICAL TRANSLATION

With the ligaments intact a vertical translation of the cranio-vertebral joints was possible to some extent with the cranium in midposition. At 19 autopsies this movement was observable both by palpation and by inspection of the change in the tension of the membrana tectoria although the movement was slight. In 4 cases measurement was made in 1 female and 3 males aged 20—47 years and the movement did not exceed 1 mm.

After removal of the membrana tectoria the possibilities of vertical translation were studied and found to be 0—1, 1—2, 1—2, 1—2, 2—3, 2—3, 3—4, 4 and 6—7 mm at 9 autopsies, 6 males and 3 females, aged 16—80 years (Table II). The average vertical translation was in these cases 2.7 mm, at most 6—7 mm and at least 0—1 mm.

DISCUSSION

The membrana tectoria thus limits vertical translation. In all positions of the head except the midposition the membrana tectoria retains a certain degree of tension. Contrary to this, the alar ligament are markedly slack in all intermediary positions. No tension appears until movements are extreme.

Checking effect of the alar ligaments on vertical translation must therefore depend on their functional length in vertical direction which varies from one case to another and in different positions of the head.

HORIZONTAL TRANSLATION

That the transverse ligament as part of the annulus osteofibrosus prevents translation along the sagittal and transverse axes is beyond all doubt (see page 32). Whether the membrana tectoria and/or the alar ligaments contribute to this function is, however, not known. Because of the importance of this question for the understanding of the consequences of insufficiency of the transverse ligament it received special attention in the present investigation.

The importance of the transverse ligament for fixation of the atlas in the horizontal plane was studied at 15 of the autopsies accounted for in Table I and in which the patients had suffered from diseases not affecting the ligaments or the joints. The material consisted of 8 males and 7 females aged 16 to 80 years. Examinations were carried out with subjects in the supine position and the head supported by a pad. The calotte and the cerebrum and medulla oblongata were removed.

In the first studies the transverse ligament was then divided with a tenotome while the other transverse ligaments were left as intact as possible. Not until the ligament had been completely divided did a ventrocaudal dislocation of the occipito-atloïd unit occur. The special ligaments running to the anterior margin of the foramen occipitale magnum thereby became loose and were thus of no importance for the mechanics of the dislocation. They were therefore removed in later studies whereby the transverse ligament and the alar ligaments were available for direct inspection.

On gradual division of the transverse ligament no change occurred in the relation between the positions of the occipito-atloid unit and the odontoid process of the epistropheus until the ligament had been completely divided. On complete division dislocation forwards of the occipito-atloid unit occurred immediately.

The alar ligaments flaccid in the midposition (see page 45) do not primarily prevent dislocation forwards. Not until the dislocation forwards of the occipito-atloid unit has assumed a certain dimension are the alar ligaments tightened and further dislocation inhibited. The extent of dislocation varied from one case to another in the 15 examinations depending on the functional length in ventral direction of the alar ligaments. The distances made between the odontoid process of the epistropheus and the anterior arch of the atlas was measured as 2, 2—3, 2—3, 3—4, 3—4, 4, 4, 4, 4, 4—5, 4—5, 4—5, 6, 6—7 and 8 mm that is on the average 4.3 mm (Table II).

The distribution among the various age groups was as follows:

Age	Number	Dislocation, mm	Mean dislocation, mm	
16—25	5	4, 4—5, 6, 6—7, 8	5.8	
26—35	0	—		—
36—45	3	2, 4, 4,		3.3
46—55	3	2—3, 3—4, 4		3.3
56—65	3	2—3, 4—5, 4—5		3.8
66—75	0	—		—
76—85	1	3—4		3.5
		4.3	5.8	3.5

It is apparent that the largest dislocations 6, 6—7 and 8 mm respectively occurred among the 5 cases in the youngest age group while the maximal dislocation among the older 10 cases was 4—5 mm.

DISCUSSION

The investigation on the ligaments of the craniovertebral joints in insufficiency of the transverse ligament confirmed the view put forwards by BELL, GREIG and WATSON-JONES that atlas dislocation is possible in insufficiency of the transverse ligament only.

In intermediary positions the alar ligaments are slack and in such positions they cannot prevent dislocation. The membrana tectoria becomes slack by the dislocation movement and thus cannot prevent dislocation either.

Partial division of the transverse ligament does not result in dislocation of the atlas and there is no reason to assume that partial rupture of the ligament should do so either. It appears that dislocation is possible only if the transverse ligament is completely insufficient.

In total insufficiency of the transverse ligament the extent of the dislocation forwards depends on the functional length in ventral direction of the alar ligaments, which seems to decrease in age groups above 35 years.

ROENTGEN INVESTIGATION OF THE MOVEMENTS OF THE OCCIPITO-ATLO-AXOID JOINTS

In the preceding sections roentgenology was employed to investigate certain details. In the study of other details, however, roentgenography could not be used because of sources of error, *e. g.* co-movement.

Since the roentgenograms in some cases can only be analysed against the background of the results of the investigation of the mechanism of the joints, it was considered convenient to discuss the roentgen-examinations in a separate chapter. A further motive for this separation was that in some cases roentgen examination can verify the results obtained in an investigation of the mechanism of the joints. Finally analysis of the normal roentgenogram was considered important for the interpretation of the roentgenogram in disease.

ANTE-RETROFLEXION

MATERIAL

Investigation of the mechanics involved on ante-retroflexion were carried out on 104 subjects (52 males and 52 females). These subjects were patients or members of the staff of the Orthopedic Clinic, Lund. The ages ranged between 10 years and 62 years (average 25.5 years). Of these subjects, 85 (80.7 per cent) fell within the 16—35 year age classes. Patients with diseases involving the region of the neck and patients with systemic diseases, widespread skeletal diseases, diseases involving the soft parts or the nerve supply were not accepted. The patients included were such as had sustained a trauma or had some local disease not involving the craniovertebral joints (Table III).

TECHNIQUE

Roentgenograms were taken during maximal anteflexion and maximal retroflexion with the patient lying on the side with the head on a pad to prevent lateral flexion and rotation.

The tube was adjusted so that the central rays passed through the tips of the mastoid processes and thus through the dorsal region of the caput dentis, *i. e.* coinciding with the assumed axis of ante-retroflexion.

The focal distance was 90 cm. The distance between the medium plane of the cranium and the film was about one fourth of this distance. Roentgenographic enlargement was thus about 25 per cent, which had no influence on the investigation of the angles of movement.

Only those examinations were accepted in which three details in the median plane of the cranium in both roentgenograms coincided by comparison: as a rule the floor of the sella turcica, the top of the hard palate and the bottom of the occipital fossa.

Roentgenograms of each subject were then studied in the following way:

1. The two roentgenograms of the cranium were placed on top of one another with the three above mentioned details coinciding, after which a line running through the roof of the palate and forming a tangent to the lower skeletal outline of the occipital bone was marked with pin pricks through the two roentgenograms (a—b and a_1—b_1 in Figs. 26 A and 26 B).

2. The films were adjusted so that the contours of the atlas coincided, after which a line running through the ventralmost and dorsalmost point of the outline of the atlas was marked with pin-pricks through both films (c—d and c_1—d_1 in Figs. 26 A and 26 B).

3. The films were adjusted so that the contours of the epistropheus coincided after which the posterior tangent to the caput dentis and corpus epistrophei was marked with pin-

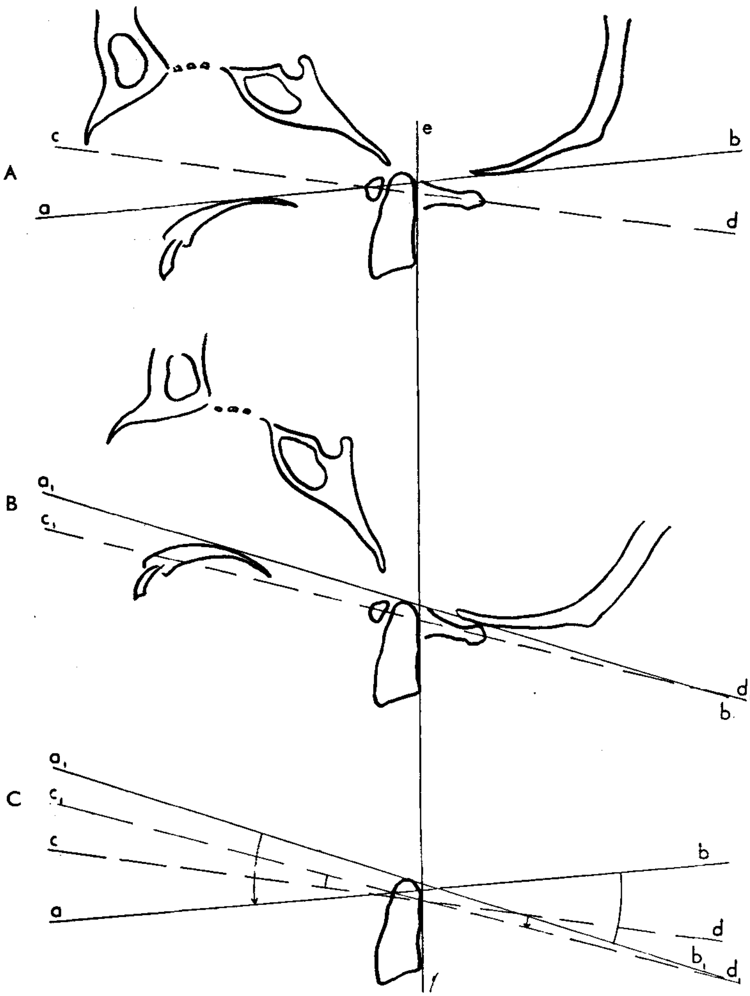


Fig. 26.

pricks through both roentgenograms (e—f in Figs. 26 A, 26 B and 26 C).

4. The pin-pricks in one roentgenogram were then transferred to drawing paper and corresponding lines drawn.

5. The other roentgenogram was then fastened to draw-

ing paper with pins through their respective pin-pricks of the posterior tangent to the caput dentis and corpus epistrophei. The pin-pricks of the other lines were then transferred to drawing paper and corresponding lines drawn (Fig. 26 C).

6. Total ante-retroflexion of the cranium in relation to the epistropheus was then measured as the angle between the two lines representing the cranium on the two roentgenograms (Fig. 26 C).

7. The total ante-retroflexion of the atlas was then measured as the angle between the two lines representing the atlas on the two roentgenograms (Fig. 26 C).

8. The movement between the cranium and the atlas was measured by the difference between the total movement of the cranium and the total movement of the atlas.

The results of these measurements are given in Table III.

ANTE-RETROFLEXION OF THE CRANIUM

The posterior tangent to the caput dentis and corpus epistrophei was selected for comparison because it can be defined exactly. The course of the otherwise usual central line through the dens (R. FICK) cannot be defined exactly, because of the varying contour of the dens (Fig. 12).

The posterior tangent of the caput dentis and epistropheus represent, roughly speaking, the continuation of the anterior contour of the spinal canal and thereby constitute, so to say, a longitudinal axis of the body or a line parallel to it. It should be possible to define the baseline of the cranium, the horizontal line or horizontal plane of the cranium in relation to this line. It appears that there is no generally accepted definition of this line or this plane except the somewhat indefinite term basis cranii. It was found that for a horizontal line of the cranium one must select a line forming a tangent to the cranial convex contour of the hard palate and the declival part of the occipital bone, Fig. 26 A, a—b. In this way it was possible to demonstrate anteflexion in relation to a line perpendicular to the above-mentioned vertical line in almost three fifths of 104

TABLE III.

1. Craniovertebral joint unit: total ante-retroflexion (°)
2. Atlo-axoid joints: ante-retroflexion (°)
3. Occipito-atloid joints: ante-retroflexion (°)
4. Occipito-atloid joints: lateroflexion (°)
5. Craniocaudal shift of anterior arch of atlas on ante-retroflexion (mm)
6. Palate-occipital tangent (see page 66): anteflexion (°)

No.	Age in years	1	2	3	4	5	6		Remarks
							+	–	
(Males)									
1	19	26	10	16		3		4.5	Distorsio dig. man.
2	19	28.5	12.5	16		1	4		Distorsio dig. man.
3	19	21.5	8	13.5		2	7		Fract. antecrur.
4	33	21.5	15	6.5		5		8	Volunteer
5	19	24	13	11		4	13		Pes plan.
6	19	18.5	8,5	10		1		6.5	Fract. navicular. man.
7	19	26	11.5	14.5		2	11		Distorsio ped.
8	21	20.5	11.5	9		0		7	Fract. ulnae
9	27	22.5	9	13.5		2		9	Fract. antecrur.
10	40	22.5	9.5	13		2		1	Contusio pollicis
11	29	21	3.5	17.5		0	9		Fract. femor.
12	33	11.5	3.5	8		0		2	Haemarthrosis gen.
13	37	14	5.5	8.5		1		15.5	Fract. mall. lat. ped.
14	33	26.5	10.5	16		3	—	—	Luxat. humeri habit.
15	30	30	18	12		7	16.5		Luxat. humeri habit.
16	19	16.5	6	10.5		0	3.5		Pes plan.
17	31	11	5	6		0		11.5	Distorsio gen.
18	20	17.5	11.5	6		2	—	—	Pes plan.
19	29	22	8.5	13.5		2	0.5		Distorsio ped.
20	17	24.5	17	7.5		3		1	Fract. antecrur.
21	31	15.5	8	7.5		3	2		Intuff. cox. sin.
22	16	23.5	19.5	4		4	0.5		Haematomyelia
23	18	17	11	6		2		8.5	Epifysoelysis capit. femor.
24	20	25	9.5	15.5		2	0.5		Contusio gen.
25	19	19.5	8	11.5		1		8	Fract. radii
26	36	34.5	15.5	19		4	—	—	Fract. antecrur
27	21	33	9	24		4	—	—	Laesio menisc. med. gen.
28	21	19.5	12.5	7		5		10	Fract. navicular. man.
29	15	41	21.5	19.5	9.5	4	9		Fract. antecrur.
30	18	34.5	17	17.5	10	4		2	Fract. antecrur.
31	15	24.5	10	14.5		4		1	Fract. antecrur.
32	10	26	9.5	16.5		2	—	—	Distorsio gen.
33	23	33	11.5	21.5		3	21		Morbus Scheuermanni
34	27	22.5	9	13.5		2	3		Lumbago traumat.
35	21	17	10.5	6.5		1		0.5	Fract. antebrach.
36	20	31	17	14		3	1		Fract. mall. lat. ped.
37	20	28	20	8		5	8		Fract. humeri
38	20	24	12	12		3	1		Distorsio pollicis
39	26	25.5	8.5	17		0	2.5		Fract. femor.

No.	Age in years	1	2	3	4	5	6		Remarks
							+	−	
40	18	26.5	6.5	20		0		4	Fract. navicular. man.
41	32	24	12	12		0		5.5	Fissura coll. femor.
42	20	31	6	25		1	9		Fract. patellae
43	16	25.5	13.5	12		3	9.5		Fract. humeri
44	33	25.5	10.5	15		1	7		Degen. disc. lumbal.
45	19	22	6.5	15.5		1	3.5		Lumbago
46	25	20	10	10		2		1.5	Degen. disc. lumbosacral.
47	46	27	9	18		2	1.5		Spondylos. cervical.
48	47	19.5	7.5	12		0	14		Brachialgia
49	32	31.5	18.5	13		3	2.5		Insuff. dorsi
50	62	16.5	7	9.5		3		5.5	Ruptur. tendin.
51	36	26.5	10	16.5		1	3.5		Brachialgia
52	44	20	8	12		1		7	Insuff. dorsi
S:a	1340	1236	562	674		114	163.5	119.5	
M	25.8	23.8	10.8	13.0		2.2	+0.8		
(Females)									
1	24	22	11.5	10.5		0	3		Volunteer
2	20	31	11.5	19.5		3	11.5		Contusio regio cubiti
3	23	27.5	11.5	16		2	4.5		Volunteer
4	23	17.5	8	9.5		2		3.5	Volunteer
5	33	28.5	8	20.5		0		0.5	Contusio regio cubiti
6	16	19	7	12		2	8		Luxatio patellae
7	13	32.5	14	18.5		2	8.5		Morbus Duchenne-Erb
8	20	20	10	10	4	2	9		Volunteer
9	22	29.5	6.5	23	7	0		4	Volunteer
10	22	32	11	21	11.5	3	10		Volunteer
11	13	28	7.5	20.5	13.5	1	8		Hydrops gen.
12	19	20	13.5	6.5	5	2	6.5		Volunteer
13	24	26	21.5	4.5	5.5	1		5	Volunteer
14	21	13	5	8	9	3		1	Volunteer
15	42	29	8.5	20.5	9	1	7		Volunteer
16	28	22.5	8.5	14		1	6		Volunteer
17	30	18	12.5	5.5		2	5.5		Volunteer
18	17	21	7.5	13.5	6	2		0.5	Volunteer
19	24	10.5	7	3.5		1		10	Distorsio pedis
20	29	21.5	10	11.5		2		1	Brevitas extremit. inf. dx.
21	29	21	2	19	4	0		2.5	Volunteer
22	21	15.5	7	8.5		0	7.5		Volunteer
23	22	20	10	10		1		7	Volunteer
24	27	31	6.5	24.5		2	3.5		Volunteer
25	20	19.5	8.5	11		2	6		Volunteer
26	14	31	19	12	8	3		11.5	Volunteer
27	26	38.5	16.5	22		4	16		Contusio cranii
28	18	9	3	6		1	21.5		Pes plan.
29	15	26	8	18		0	3.5		Osteochondrit. diss. gen.
30	16	16.5	5	11.5		0	11		Luxatio patellae

No.	Age in years	1	2	3	4	5	6		Remarks
							+	−	
31	28	14.5	6.5	8		0	3.5		Volunteer
32	26	32.5	10.5	22		1	13		Volunteer
33	31	16	5	11		0	9		Volunteer
34	27	39.5	7	32.5		0	4		Volunteer
35	23	20.5	6.5	14		2		7	Volunteer
36	19	27.5	6.5	21		1	9		Volunteer
37	34	16	5.5	10.5		1	2.5		Degen. disc. lumb.
38	27	22	14	8		3	5		Brachialgia
39	38	20	11.5	8.5		2	15.5		Lumbo-ischias
40	34	21	6.5	14.5		1		2.5	Degen. disc. lumbo-sacral.
41	35	26	6	20		0	8		Degen. disc. lumb.
42	39	18.5	9.5	9		1	18		Insuff. dorsi
43	26	20	7	13		0	7		Spondylos. cervical.
44	18	18	6.5	11.5		0		4	Degen. disc. lumbo-sacral.
45	33	25	8	17		2		1	Lumbo-ischias
46	17	29	9	20		2	11		Lumbago
47	33	29	15.5	13.5		0	19		Spondylos. cervical.
48	32	26	13.5	12.5		2	13		Dolores articul.
49	44	10	7.5	2.5		1	2.5		Insuff. dorsi
50	29	20	9	11		1	7		Brachialgia
51	27	29	12.5	16.5		4	15.5		Degen. disc. lumbo-sacral.
52	18	22	13	9		2	10		Brachialgia
S:a	1309	1199	482.5	716.5		71	329	61	
M	25.2	23.1	9.3	13.8		1.4	+5.2		

examinations (Table III). Compare line a—b in relation to line e—f in Fig. 26 A.

Since individual variations decide the occurrence, if any, of an average minimal ante-flexion of 3° for the craniovertebral joints, it would perhaps be more correct to speak only of retroflexion in these joints. The question of exact definition of movement during ante-retroflexion is probably of no practical importance. Movement can be divided into two different parts or it may be described simply as ante-retroflexion or movement about the transverse axes of the occipito-atlo-axoid joints. Here anteflexion or retroflexion are to be understood only as indicating the direction of movement.

The range of movement of the joints under consideration as seen in the roentgenograms are described on pages 74—78.

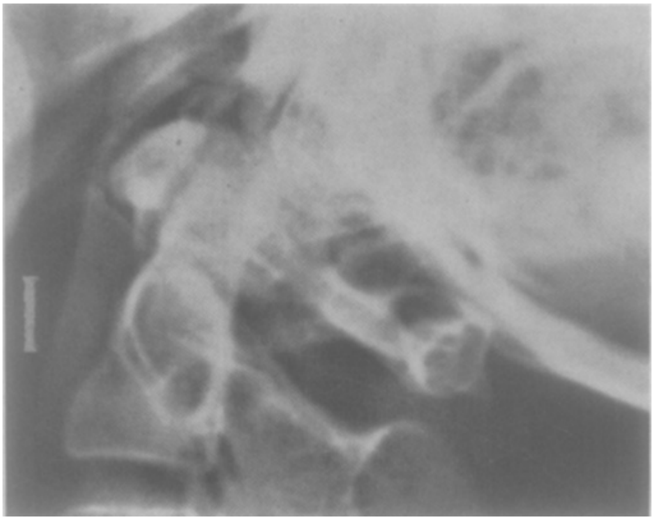


Fig. 27.

ANTE-RETROFLEXION OF THE ATLAS

The mechanism of the ante-retroflexion of the atlas was described on pages 29—31 and the results of measurements of the range of movement are accounted for in corresponding anatomic studies on pages 74—78.

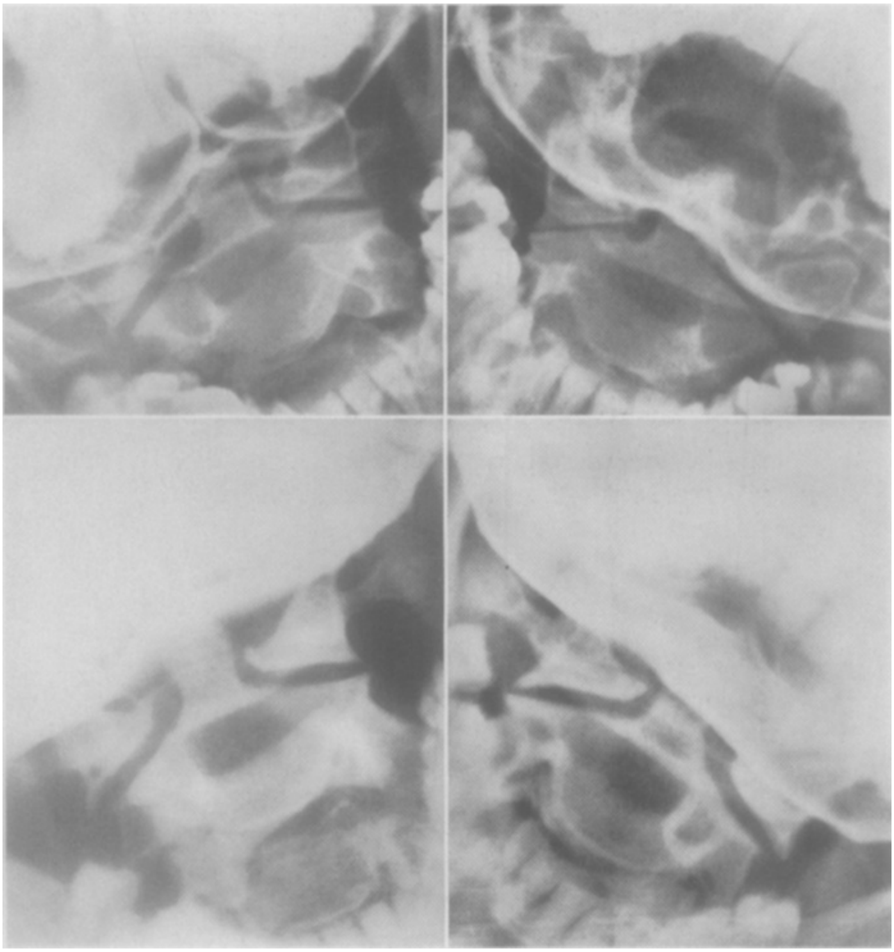
COMMENTS

In somewhat more than half of 104 roentgen-examinations skeletal contact appeared to exist between the posterior arch of the atlas and the occipital bone on retroflexion in the occipito-atloid joints (Fig. 27). In the remaining cases there was a varying diastasis up to 10 mm.

Skeletal contact between the posterior arch of the atlas and the occipital bone should therefore probably be regarded as a possible factor limiting retroflexion in the occipito-atloid joints.

LATEROFLEXION AND ROTATION

As pointed out earlier, lateroflexion in the occipito-atloid joints is associated with a rotation of the anterior surface of



A

B

Fig. 28.

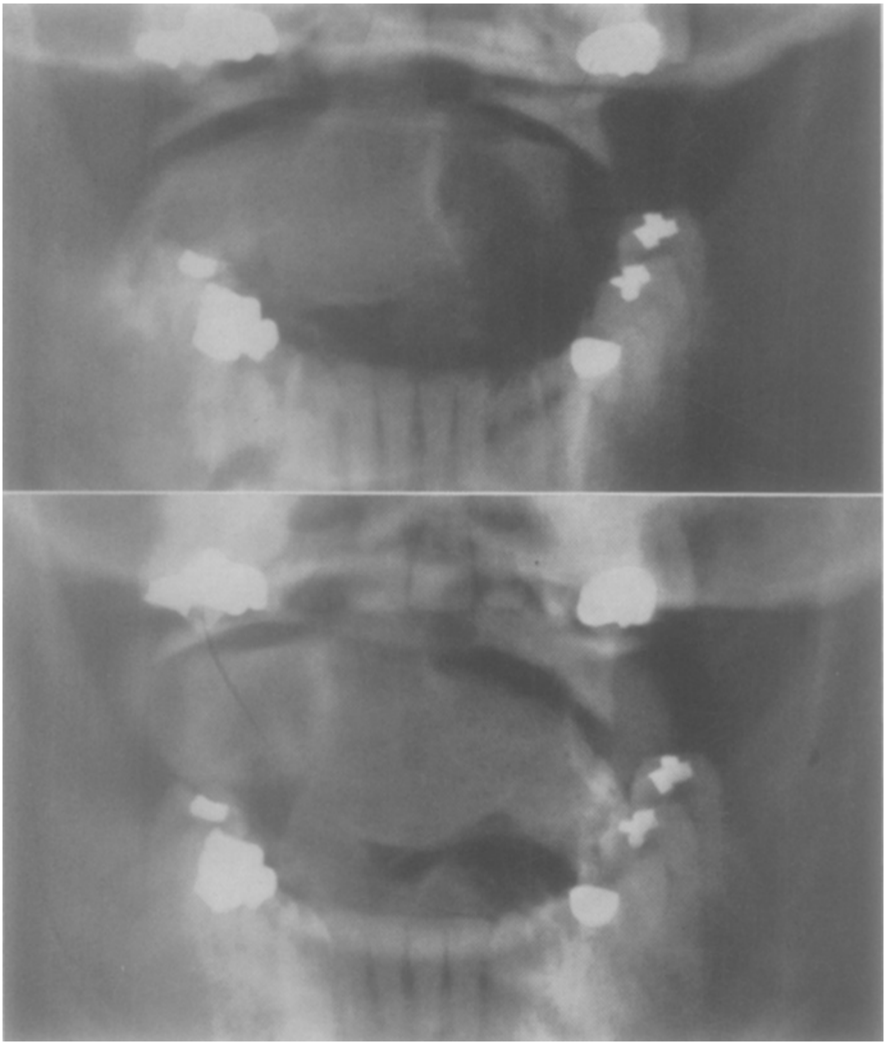
the epistropheus in the direction of lateroflexion. On roentgen examination of 13 subjects selected at random from the above-mentioned material (2 males, 11 females aged 13 to 42 years with an average age of 21.2) this was confirmed in that the epistropheus on maximal lateroflexion always appeared asymmetric in frontal views (Fig. 28).

In order to confirm the combination of the movement of the occipito-atloid and atlo-axoid joints on rotation in the occipito-atloid joints examinations were carried out on a 44 years old male subject. During examination the head was immobilised. As expected, on rotation of the trunk lateroflexion occurred in the occipito-atloid joints in the direction of the rotation (Fig. 29).

COMMENTS

The asymmetry of the outline of the atlas and the anterior part of the epistropheus on lateroflexion of the occipito-atloid joints on the side to which the lateroflexion is directed has led to the misconception that the atlas is displaced laterally over the epistropheus and thereby partakes in lateroflexion (HULTKRANTZ, BAKKE, DANKMEIJER & RETHMEIER, POIRIER & CHARPY, COUTTS). JACOBSON & ADLER also shared this view but they observed rotation of the epistropheus, a rotation for which they could, however, offer no explanation.

As shown earlier (see page 32) lateroflexion and/or transverse translation of the atlo-axoid joints is anatomically impossible. Since roentgen examination did not suggest any such movement either, it may be concluded that the earlier conception put forward by the above-mentioned authors was erroneous.



Right Left *

Fig. 29.

A. Rotation of the trunk to the left.
B. Rotation of the trunk to the right.

* All roentgenograms in sagittal or axial projection illustrated in this paper the reader should imagine the subject en face.

RANGES OF MOVEMENT OF THE CRANIOVERTEBRAL JOINTS

In connection with the post-mortem examinations (Table I) and the roentgen examinations (Table III) the range of movement of the craniovertebral joints was noted. The ranges found did not, however, agree well with those usually given as normal on the basis of earlier investigations of R. FICK (1904—1911) and POIRIER & CHARPY (1926).

It might therefore be of interest to account for the results found in the present investigation.

The ranges of movement of the cranium and of the atlas were judged in relation to the epistropheus; roentgenographically, in relation to a median vertical line in a transverse plane forming a tangent with the dorsal contour of the caput dentis and corpus epistrophei and, post mortem, in relation to a steel pin passed through the apex dentis into the collum dentis and coinciding as closely as possible with the vertical axis of the craniovertebral joints.

The material and the results of examination are given in Tables I and III and, as far as the post-mortem examinations are concerned, the results are also summarized below in Table IV.

RANGE OF ANTE-RETROFLEXION

The complete range of ante-retroflexion in the craniovertebral joints was studied post-mortem in 6 male subjects and 8 female subjects, aged 19 to 82 years (average 51.2 years). The mean range of ante-retroflexion was found to be 29.8° (max. 41°, min. 18°). The technique employed in these examinations was accounted for earlier (page 53).

TABLE IV.

Case No.	Age in years	Sex	Ante-retro-flexion (°)	Latero-flexion (°)	Rotation (°)	Vertical translation (mm)
I	20	M				0—1
II	47	M			37	0—1
III	45	F			41	0—1
IV	22	M		10		0—1
V	16	F		10	52	
VI	80	M	22	6	49	
VII	61	M	18	12	51	
VIII	55	M	28	14		
IX	34	F	41	12	59	
X	82	F	36	10	53	
XI	64	M	36	8	63	
XII	48	F	25	12	39	
XIII	56	F	33	6	45	
XIV	60	F	36	16	41	
XV	56	F	36	13	42	
XVI	19	M	36	16	58	
XVII	36	F	24	19	46	
XVIII	41	F	28	12	47	
XIX	25	M	18	14	22	
Total			417	190	745	
Number			14	16	16	
Mean age in years			51.2	47.2	48.1	

The range of ante-retroflexion was also studied roentgenographically in lateral views taken on maximal anteflexion and maximal retroflexion. The roentgen technique and measuring technique are described on page 64.

The total active range of ante-retroflexion of the cranium as seen at roentgen examination of the 104 cases (Table III) was found to be on the average 23.4° (max. 39.5°, min. 9°). Ante-retroflexion of the atlas was on the average 10.0° (max. 21.5°, min. 2.0°). The remainder of the total ante-retroflexion of the cranium is thus ascribable to movement in the occipito-atloid joint, *i. e.* 13.4° (max. 32.5°, min. 3.5°).

The roentgen examinations were performed on 52 male subjects, aged 10 to 62 years (average 25.8 years) and 52 female subjects, aged 13 to 44 years (average 25.2 years). The total range of ante-retroflexion did not differ with sex (average 23.8° for males and 23.1° for females). Neither was any difference found between the range of this movement in younger and older subjects. In the 10 to 23 year age classes consisting of 53 subjects of both sexes the average range was 24° and in the 24 to 62 year age classes consisting of 51 subjects of both sexes the corresponding value was 23°. The younger males and the older females showed the highest averages, namely 25° and 23.3° respectively. The 23 males in the higher age classes and the 28 females in the lower age classes showed the lowest average values, namely 22.2° and 22.7°.

RANGE OF LATEROFLEXION

Lateroflexion was studied post mortem in 16 subjects, 7 males and 9 females, aged 16 to 82 years (average 47.2 years). This range of movement was found to be 11.9° (max. 19°, min. 6°).

Measurement of active lateroflexion was made in sagittal views taken through the mouth on maximal lateroflexion to either side, after which the total range of lateroflexion was determined as the angle between the atlas contours in the two superimposed craniocongruent roentgenograms. As measured in 13 subjects, 2 males and 11 females, aged 13 to 42 years (average 21.2 years) total lateroflexion was found to be 7.8° (max. 13.5°, min. 4.0°).

RANGE OF ROTATION

Examinations post mortem by the technique described on pages 57 and 58 and Figs. 23—25 on a series consisting of 6 males and 10 females, aged 16 to 82 years (average age 48.1 years) showed an average range of rotation of 46.6° (max. 58°. min. 22°).

DISCUSSION

The difference between the total range of movement of the craniovertebral joints, as judged by the two methods of examination must be considered as surprisingly small if it be borne in mind that post mortem the normal turgor of the tissues and the expansion of the muscles due to contractions are eliminated. The force applied in the examinations post mortem must also be borne in mind as possibly too high, especially through the leverage implied by application of force to the periphery of the cranium.

Moreover, in examination of active movement, it is doubtful whether the subject really bends the head to an extreme position and holds the head in such a position until the examination is finished.

Nothing argues against the average values found, 23° and 30° respectively being representative means for active and passive ante-retroflexion of the craniovertebral joints.

In the measurement of lateroflexion post mortem it must be recollected that this movement is combined with rotation of the dens. For the measurement to be exact, the steel pin must therefore exactly coincide with the axis of rotation.

The correctness of the position of the steel pin thus decides the measuring error of the method. Since the axis passes centrally through the collum dentis, it should pass through or form a tangent to the anterior edge of the foramen occipitale magnum. In the positioning of the steel pin the anterior edge of the foramen occipitale magnum and the intermediate soft parts should prevent forward inclination of the steel pin. On the other hand, backward deviation of the steel pin in relation to the vertical axis is often probably unavoidable, firstly to avoid skeletal contact with the cranium and secondly in order to be able to fasten the pin in the marrow cavity through the usually backwardly curved cranial part of the dens (Fig. 12).

On lateroflexion the anterior surface of the epistropheus rotates in the same direction as the lateroflexion which implies that on rotation the backward deviation of the steel pin will cause the measurement of lateroflexion to be too large. On average rotation of 47° the erroneous addition due to the incline of the pin must be between one twentieth and one fourth of the incline of the pin and thereby represent a considerable source of error. The value found for lateroflexion post mortem must therefore be regarded as too high. As to the roentgen examinations, the results appear to be free from any such source of error, since then lateroflexion is judged directly between the cranium and the atlas. Rotation is also combined with lateroflexion of the cranium. Since this lateroflexion, as pointed out earlier, is only about 4° in either direction, it may be regarded as a negligible source of error.

No practical method is available for radiologic measurement of rotation.

Since rotation is obviously controlled entirely by the special craniovertebral ligaments, there is no reason to suppose any source of error of importance to have influenced the results of measurements post mortem.

For comparison the values found are compared below with those of R. FICK and POIRIER & CHARPY.

	R. FICK	POIRIER & CHARPY	Values found
Craniovertebral joint unit			
Ante-retroflexion	50°	61°	23° (9—41°)
Lateroflexion	30—40°	18—44°	8° (4—13.5°)
Rotation	60°	30—80°	47° (22—58°)
Occipito-atloid joints			
Ante-retroflexion	50°	50°	13° (3.5—32.5°)
Lateroflexion	30—40°	14—40°	8° (4—13.5°)
Atlo-axoid joints			
Ante-retroflexion	insignificant	11°	10° (2—21.5°)
Lateroflexion	0	4 mm	0
Rotation	60°	30—80°	47° (22—58°)

TO SUMMARIZE, on the basis of theoretical studies, model experiments, and literature studies it was concluded that guiding articular contact is necessary for the existence of a biaxial joint, whose axes cross one another at right angles in different planes. The analysis showed that such contact can exist and thereby disproves an earlier assertion of R. FICK. On the other hand, it was found that HENKE's assumption that the *occipito-atloid joint unit* is biaxial is physically possible.

In contrast to what is widely believed, the alar ligaments are slack when the head is in midpositions.

During the last decades it has been assumed that the atlo-axoid joint unit is triaxial. In the present investigation, however, it was shown that the mechanics of the joints are such as not to permit movement about a sagittal axis.

R. FICK doubted the possibility of movement about a transverse axis in the *atlo-axoid joint unit* on the supposition that the transverse ligament and anterior arch of the atlas would prevent such a movement. However, observations made in the present investigation confirm the occurrence of ante-retroflexion in the atlo-axoid joints. The mechanical requirements for such movements were also investigated. The transverse axis can shift somewhat sagittally, but runs approximately through the centre of the annulus osteofibrosus.

According to R. FICK, the vertical axis of the atlo-axoid joint unit runs centrally through the dens. This line is, however, irregular. In addition, the vertical axis is probably not a fixed axis. However, it extends through the centre of the annulus osteofibrosus, but can probably deviate somewhat in the sagittal plane and on rotation of the atlas in the transverse plane depending on the slope of the articular surfaces of the intervertebral joints of the epistropheus.

On investigation of the *factors limiting the range of movement in the craniovertebral joints* it was found that the range of anteflexion in the occipito-atloid joints is limited by skeletal contact between the anterior margin of the foramen occipitale magnum and the apex dentis via an interposed bursa. Since this bursa has apparently not been described earlier in the literature, it is termed ***bursa apicis dentis.*** According to the literature, anteflexion in the occipito-atloid joints is inhibited by the intraspinal ligaments of the craniovertebral joints. Because of the position of the transverse axis, these ligaments cannot have such a function. Retroflexion in the occipito-atloid joints is on the other hand inhibited by the membrana tectoria.

Limiting lateroflexion in the occipito-atloid joints has been ascribed to a unilateral effect of the alar ligaments. A unilateral effect of the alar ligaments, however, leads above all to rotation of the epistropheus. This results in a tightening of the contralateral alar ligament. The combined movement, lateroflexion in the occipito-atloid joints with rotation in the atlo-axoid joints then is inhibited by an interplay between the two alar ligaments.

Anteflexion in the atlo-axoid joints is checked by the fact that the membrana tectoria is tightened with the caput dentis as a fulcrum. Because of the position of the transverse axis this fulcrum effect is necessary for the membrana tectoria to be able to check anteflexion. Retroflexion of the atlo-axoid joints is checked by the membrana tectoria indirectly by simultaneous retroflexion in the occipito-atloid joints.

Rotation in the atlo-axoid joints is believed to be checked by a unilateral effect of the alar ligaments. The unilateral effect of the alar ligaments, however, results in a lateroflexion in the occipito-atloid joints, whereby the contralateral alar ligament is tightened and inhibits lateroflexion. The combined movement, rotation in the atlo-axoid joints and lateroflexion in the occipito-atloid joints, is then inhibited by an interplay between the alar ligaments.

It was found that an interplay occurs between the special craniovertebral ligaments in two ways, in that they have inhibitory functions through the membrana tectoria and the alar ligaments and, secondly, stabilising functions through the transverse ligament and the membrana tectoria.

In its checking effect the membrana tectoria is supported by the alar ligaments during ante-retroflexion and the alar ligaments are supported by the membrana tectoria in their checking of rotation and lateroflexion.

Normally the transverse ligament exerts no checking effect on craniovertebral movements. It does, however, represent a part of the annulus osteofibrosus. On loss of function of the transverse ligament the occipito-atloid unit would be capable of translation in the horizontal plane. Excursions during these movements are limited by the alar ligaments. Since the atlo-axoid joints from a functional point of view are interposed between the origins and the attachments of the alar ligaments and membrana tectoria, this ligaments are dependent on the stability of the atlo-axoid joints for their function. In this respect there is thus an interplay also between the transverse ligament on one hand and the membrana tectoria and the alar ligaments on the other.

The atlo-axoid joints show, according to HENKE, normally a certain vertical translation as a screw movement during rotation, but further translation, glapping, is prevented by the fact that the alar ligaments were continously tight. The alar ligaments are, however, tight only in extreme rotation or lateroflexion positions and can thus not have such a function. HECKER ascribed the same function to the transverse ligament in that the caput dentis and the annulus osteofibrosus should function like a button in a button hole. No such function could, however, be demonstrated. Play in the craniovertebral joints is prevented by the membrana tectoria, which practically speaking, in all positions retains a certain degree of tension. The membrana tectoria thus has also a function as a stabilising ligament for the craniovertebral joints.

In these investigations the values for the normal range of movement of the craniovertebral joints were noted and were found to differ considerably from those usually given in the literature. Since it might be of a certain clinical interest to know to what extent movement of the head is due to movement in the craniovertebral joints, the values are accounted for.

To gain surveyability the axes of movement, the ranges of movement, and the main factors of inhibiting movement of the craniovertebral joints are recapitulated in the following tables:

Axes	Type of movement	Range of movement	Main movement-inhibiting factors
	OCCIPITO-ATLOID JOINTS		
I. Transverse axis (through the mastoid processes)	Ante-retroflexion	about 13° (3.5—32.5°)	*Anteflexion* Skeletal contact via bursa apicis dentis, between the anterior margin of the foramen occipitale magnum and caput dentis. *Retroflexion* Membrana tectoria (possibly skeletal contact between the posterior arch of the atlas and the occipital bone).
II. Sagittal (extending about 2 cm cranially to the apex dentis	Lateroflexion (combined with rotation in the atlo-axoid joints	about 8° (4—13.5°)	*Dextroflexion* Ligamentum alare sinister with counter-pull of ligamentum alare dexter. *Sinistroflexion* Ligamentum alare dexter with counter-pull of ligamentum alare sinister.
	ATLO-AXOID JOINTS		
I. Transverse axis (approximately through the centre of the annulus osteofibrosus	Ante-retroflexion	about 10° (2—21.5°)	*Anteflexion* Membrana tectoria (with caput dentis as hypomochleon). *Retroflexion* Membrana tectoria by counter-pull to the outer anterior ligaments.
II. Vertical axis through centre of annulus osteofibrosus	Rotation (combined with lateroflexion in occipito-atloid joints	about 47° (22—58°)	*To the right* Ligamentum alare sinister with counter-pull of ligamentum alare dexter. *To the left* Ligamentum alare dexter with counter-pull of ligamentum alare sinister.

Axes	Type of movement	Range of movement	Main movement-inhibiting factors
	CRANIOVERTEBRAL JOINT UNIT		
I. Transverse axis of the occipito-atloid joints II. Transverse axis of the atlo-axoid joints	Ante-retroflexion	about 23° (9—41°)	*Anteflexion* Skeletal contact for the occipito-atloid joints and membrana tectoria for the atlo-axoid joints. *Retroflexion* Membrana tectoria (possibly skeletal contact in the occipito-atloid joints.
III. Sagittal axis of the occipito-atloid joints.	Lateroflexion	about 8° (4—13.5°)	Ligamenta alaria.
	and		
IV. Vertical axis of the atlo-axoid joints	Rotation	about 47° (22—58°)	Ligamenta alaria.

ATLAS DISLOCATION

Chapter IV

EARLIER INVESTIGATIONS

The first to describe a verified case of dislocation (luxation, subluxation) of the atlas because of rupture of the ligamentum transversum atlantis was BELL 1830. In a report of a neurologic investigation he described a case that has often been referred to by later workers in this field. In this patient, who suffered from a syphilitic ulceration of the pharynx, death was preceded by two hour's apoplectic symptoms. Post-mortem examination showed rupture of the transverse ligament to be the cause of death. The atlas had been dislocated and had compressed the cord.

In 1855 MALGAIGNE gave a detailed clinical survey of various types of dislocation of the atlas. He classed dislocations of the atlas as traumatic or pathologic according to etiologic factors, and in forward or backward according to the main direction of the dislocation.

BLASIUS (1868) by including all dislocations of the atlas under the heading of traumatic vertebral luxations seems, since he has often been referred to, mainly responsible for the wide belief in the traumatic origin of dislocations of the atlas, a concept that remained unchallenged fo several decades.

At the turn of the century, however, descriptions appeared of dislocation of the atlas in association with rheumatic affections. Thus BÖGER (1905), for example, reported a case under the name of malum suboccipitale rheumaticum.

WITTEK (1908) was the first to direct attention to the fact that dislocation of the atlas might follow an infection not directly involving the region of the atlas; in his case the patient had an alveolar periostitis.

Thanks to the work above all of JACOBS (1918), GRISEL

(1930), DESFOSSES (1930), GREIG (1931), and WATSON-JONES (1932) spontaneous dislocation of the atlas has gradually been defined as a form of acquired torticollis with insufficiency of the atloid transverse ligament and dislocation of the atlas. It occurred in connection with or after acute or chronic infections involving the base of the skull or the upper cervical region.

The term "spontaneous" was introduced by WATSON-JONES in the name "spontaneous hyperaemic dislocation of the atlas". Synonyms appearing in the literature of the last few decades are malum suboccipitale rheumaticum (BÖGER 1905), Distensionsluxation (WITTEK 1908), Drehungsverrenkung (SUDECK 1923), torticollis nasopharyngien (GRISEL 1930), maladie de Grisel (DESFOSSES 1930), non-traumatic subluxation (BERKHEISER & SEIDLER 1931), and dislocation non traumatique (BOEVER & HENNEBERT 1953) as well as other similar or more descriptive terms. The name spontaneous dislocation of the atlas appears to be preferred because it distinguishes the condition from traumatic dislocation of the atlas, and on the other other hand says nothing about the ethiology and pathogenesis, questions which in several papers appearing in the last few decades have been left open to discussion (DELGOFFE 1934, HESS et al. 1935, WILSON et al. 1940, SULLIVAN 1949).

Spontaneous dislocations of the atlas have been described in association with rhinopharyngitis (GRISEL 1930, DESFOSSES 1930, WATSON-JONES 1932), tonsillitis (SWANBERG 1919, GRISEL 1930), retropharyngeal abscess (LOUNAVAARA 1949), scarlatina (HESS et al. 1935), alveolar periostitis (WITTEK 1908), mastoiditis (TEDESCO et al. 1930, WATSON-JONES 1932), acute rheumatic fever (JACOBS 1918, BERKHEISER & SEIDLER 1931, COUTTS 1934), chronic polyarthritis (ELY 1911, KORNBLUM et al. 1952), syphilitic pharyngeal ulcer (BELL 1830), tuberculous lymphoma of the neck (WATSON-JONES 1932) etc.

WITTEK (1908) presumed that the ligaments in the occipito-atlo-axoid joints could be stretched by a "metastatic effusion" in these joints due to a periostitis of the jaw. A spontaneous atlas dislocation was then possible. In accordance with this theory WITTEK suggested the term distension luxation for this type of dislocation. JACOBS (1918), BERKHEISER & SEIDLER (1931), WILSON et al. (1940), and SULLIVAN (1949) shared this opinion.

GRISEL (1930) had observed aquired torticollis in association with infectious diseases in the nasopharyngal region. He claimed that inflammatory irritation of the attachments of the deeper neck muscles could cause muscular spasms, which, according to him, was the direct cause of torticollis. He thought that in some cases dislocation of the atlas might occur because of the muscle spasm being so severe that the atlas was enucleated forward between the epistropheus and the occipital bone in the same way as a cherry stone can be squeezed out by pressing it between the finger and thumb.

GREIG (1931) claimed that the vertebral ligaments are normally so strong that they cannot be torn off without simultaneous avulsion of a fragment of the bone to which they are attached. Such fractures would thus be necessary for the development described by GRISEL, but no such fractures were seen in these atlas dislocations. Therefore, according to GREIG, one must suppose a pathologic process in the transverse ligament or its attachments to precede the dislocation. According to GREIG, the adjacent vertebrae cannot escape being involved by the hyperaemia occurring in association with an inflammatory process in the region of the neck. Such hyperaemia results in decalcification of bone substances (LERICHE & POLICARD 1926). Loosening of the transverse ligament owing to such decalcification is, according to GREIG, the obvious explanation of the dislocation, because if the ligament with its weakened attachment is subjected to strain it may loose its grip on the bone. WATSON—JONES (1932) shared this view.

Opinions thus differ about the strength of normal craniovertebral ligaments. A brief survey of earlier investigations in this point might therefore be useful.

ORFILA (1840) assailed the then prevalent opinion that hanging caused dislocation of the atlas. He claimed that neither legal hanging nor suicidal hanging results in dislocation of the atlas. ORFILA referred to some 50 postmortem reports of legal hanging in England and to similar reports of suicidal hanging in France and stressed that the formerly prevalent opinion had not been based on reports of postmortem examinations.

WOOD-JONES (1931) analysed the injuries caused from fall-board-hanging, and found that the cause of death varied with the position of the running knot: in suboccipital hanging it was strangulation; in subauricular hanging, either strangulation or longitudinal lateral fracture of the base of the skull; and in submental hanging, a fracture of the arch of the second cervical vertebra with compression of the cord. He pointed out that this had already been shown by a committee of 1886.

These investigations thus show that craniovertebral ligaments are normally extremely strong. A search of the literature failed to reveal reports of the tolerance of those ligaments to violence in vivo other than extension.

The interval between the onset of an inflammatory disease and a spontaneous dislocation of the atlas appears to vary widely. It is not possible from the literature to form a clear opinion of the average interval. In many cases no mention is made of the interval or, if so, it is given in relation to some operation without any information about the duration of the previous disease. Calculated from the onset of an infection it can occur even within one day (GRISEL, WATSON-JONES, and others), while in chronic rheumatic diseases it might be several years (BOEVER & HENNEBERT). WATSON-JONES gives an interval of 7 to 10 days as the most common. In BOEVER & HENNEBERT's series the interval was a week or less in 13 out of 27 cases which had not been submitted to operation.

The subsequent course is believed to vary with the extent of the dislocation (WATSON-JONES) or with the type of the dislocation (MALGAIGNE, BERKHEISER & SEIDLER, HESS et al., SULLIVAN, BOEVER & HENNEBERT). Usually three types of dislocation are distinguished, *i. e.* unilateral forwards, unilateral backwards and bilateral forwards.

The commonest type is unilateral dislocation forwards (MALGAIGNE, JACOBS). In right-sided dislocation of the atlas forwards the head is turned to the left, bent to the right and forwards. The spinal process of the atlas follows the external protuberance of the occipital bone in the development of the rotational position of the head, and the spinal process of the epistropheus then lies to the left of the external protuberance of the occipital bone (MALGAIGNE, SUDECK). If the dislocation of the atlas is pronounced, the anterior arch may be felt as a forward bulge in the retropharynx (MALGAIGNE, SWANBERG). In such cases the spinal process of the epistropheus may bulge out in the neck.

In right-sided dislocation backwards the head is said to be rotated to the right and the spinal process of the epistropheus to be palpable to the right of the inion. The anterior arch of the atlas does not bulge into the retropharynx (BERKHEISER & SEIDLER, HESS et al.).

In bilateral dislocation forwards there is at most slight rotation of the head. The head is bent forward and the arch of the atlas bulges into the retropharynx (MALGAIGNE, BERKHEISER & SEIDLER).

According to WATSON-JONES (1932), the immediate issue of development of spontaneous dislocation of the atlas is said to vary with the extent of rupture in the transverse ligament and complete rupture may be fatal.

Small dislocations with only symptoms of torticollis are most common (WATSON-JONES, BOEVER & HENNEBERT, and others), while dislocations so extensive as to produce neurologic symptoms because of cord compression are less common. In BOEVER & HENNEBERT's series neurologic symptoms were reported in 15 of 103 cases. The neurologic symptoms are due to cord compression and in mild cases manifest themselves in the form of paresthesiae or disturbed reflexes. In severe cases paresis can be extensive in the extremities and the trunk. Cases with quadriplegia are on record (BERKHEISER & SEIDLER, WATSON-JONES, WILSON et al., RAMOND, TITRUD et al., MARGULIES et al. 1955).

The diagnosis of spontaneous dislocation of the atlas is generally regarded as being simple, provided that the examiner is acquainted with the condition. According to JACOBS (1918), spontaneous torticollis must a priori be suspected of being due to spontaneous dislocation of the atlas. A history including any infectious process in the upper region of the neck or base of the skull makes the diagnosis still more probable (GRISEL, WATSON-JONES, SULLIVAN, GROGONO). Painful contraction of the upper neck muscles, support of the head with the hands on change of posture (MALGAIGNE, GROGONO), gibbosity in the upper neck region with the external protuberance of the occipital displaced laterally in relation to the spinal process of the epistropheus (MALGAIGNE, SUDECK), and possibly an anterior bulging of the arch of the atlas into the retropharynx (MALGAIGNE, SWANBERG) can confirm the diagnosis.

In most cases the diagnosis might be verified by roentgen-examination in ordinary projections (SWANBERG, WATSON-JONES, SULLIVAN, GROGONO). Lateral projections often show a diastasis between the anterior arch of the atlas and the odontoid (WATSON-JONES, SULLIVAN, GROGONO). In the antero-posterior or sagittal view the joint space of the dislocated intervertebral joint is reduced or disappeared, because of superimposition of the joint processes (SULLIVAN, GROGONO, BLOUNT).

Although the diagnosis is regarded as offering no difficulties, it seems to have been missed very often, even in the presence of serious symptoms (SWANBERG, SUDECK, BERKHEISER & SEIDLER, BROOKES, BLUNCK, SULLIVAN, BOEVER & HENNEBERT, KOTSCHER). It is not unusual, for instance, that such patients have been obliged to support the head with the hands for some time before the condition is finally diagnosed (SULLIVAN, KOTSCHER). It may also be possible for a patient to die without the dislocation having been diagnosed.

In the establishment of a differential diagnosis one must bear in mind the possibility of congenital torticollis, in which the position of the head is the same as that seen in spontaneous dislocation of the atlas, but with contracture or fibrosis of the sternocleidomastoid muscle on one side. This muscle is not involved in spontaneous dislocation of the atlas (WATSON-

JONES). In addition various skeletal diseases such as fractures or luxations of the lower vertebrae (SUDECK) osteitic processes and especially syphilis and tuberculosis (BOEVER & HENNEBERT) must be borne in mind.

According to WATSON-JONES (1943 and 1955) spontaneous atlas dislocation occurs mainly between the ages of 6 and 12 years. In their material of 28 cases WILSON et al. (1940) found the majority to fall within the 5—12 year age group. In SULLIVAN's (1949) series of 56 cases 76.8 per cent were seen in children below 13. The average age was 12.2 years. Cases have, however, been reported from earliest infancy (LOUNAVAARA 1949) up to 62 years of age (WILSON et al. 1940).

WILSON et al. found the condition to be equally common in both sexes. SULLIVAN reported a slight preponderance for females (54 per cent), but since his material consisted of only 56 cases, the sex distribution may be considered as equal even in his series.

In BOEVER & HENNEBERT's (1953) collection of non-traumatic dislocations of the cervical vertebrae there were 103 cases of atlas dislocation, and this represents the largest collection of so-called spontaneous atlas dislocation on record. An earlier collection of SULLIVAN (1949) appears to have been unknown to BOEVER & HENNEBERT because 24 of the 56 cases in that series were not accounted for by BOEVER & HENNEBERT. With these 24 cases the total would be 127.

Perusal of the literature, however, revealed further cases which might reasonably be classified as spontaneous atlas dislocation. These cases are often accounted for under symptomatic diagnoses. On the other hand, some cases are classified under the heading of traumatic atlas dislocation even in the absence of known trauma, obviously because of lack of any known or accepted origin. Finally, it appears that even since the nature of so-called spontaneous atlas dislocation has become known, there is a tendency to ascribe etiologic importance to the most trivial trauma, which hardly appears justified.

BELL's collection included in addition to the case (No. 62) mentioned above, a further two of great interest which had not been referred to earlier as atlas dislocations. In the one case (No. 61) the patient was a man who, while pushing a barrow over a pavement stone, collapsed and died. Postmortem examination showed that the transverse ligament had ruptured, the atlas was dislocated forwards and the cord was compressed. The other (No. 64) was described as a case of torticollis. The patient was a boy aged 16, who three months earlier had had a cold with a sore throat. After the cold had passed off he noticed a swelling of the back of the neck which gradually increased. At the same time paresthesiae began to occur in all limbs and finally he had right-sided hemiplegia, for which he sought medical advice. An osteitic process was suspected. Bilateral paravertebral incisions in the neck were followed by a copious flow of blood but apparently no pus, because not until 10 days later was any formation of pus observed in the wound. By then the patient had a quadriplegia and paresis of the trunk. Movement of the head was painful and the patient was treated with immobilisation of the neck. He was described as improving after 1 year by when he had full control of the limbs, but the right arm was still weak. MALGAIGNE (1855) described 2 cases of his own in which the patients died from intervening diseases after 7 months and 8 years, respectively. In both of these cases postmortem examination showed insufficiency of the transverse ligament and the alar ligaments. Since such combined insufficiency must in the opinion of the writer be fatal, there is reason to suspect that the dislocation of the atlas was due to insufficiency of the transverse ligament only. In the patient who died at 8 years and in whom the dislocation of the atlas occurred at the age of 6 months, an osseous ankylosis had developed between the occipital bone and the three upper cervical vertebrae.

LOB (1930) described a child, a boy, aged 4, who after 10 day's fever developed torticollis and after 4 weeks also right-sided hemiparesis, which disappeared together with the fever after a further 14 days. However, the torticollis persisted. LOB described the clinical picture as a consequence of osteomyelitis with atlas dislocation because of erosion of the odontoid process. However, examination of the reproductions of the roentgenograms given show that the odontoid process was of normal appearance. The dislocation of the atlas was therefore probably due to insufficiency of the transverse ligament.

Under the heading of cervical rheumatism with quadriplegia GARNIER & DELON (1930) described an interesting case in a boy, aged 13, in whom the condition should rather be regarded as spontaneous dislocation of the atlas. The roentgenologist reported the occurrence of increased diastasis between the epistropheus and the anterior arch of the atlas. The patient was treated with traction for 6 days and the quadriplegia ceased.

COUTTS's (1934) series is not included in earlier compilations. The material is so well presented and described that the cases must be regarded as verified, although no case reports are given. It consisted of 21 cases of subluxation of the atlas which were seen at the New York Orthopaedic Dispensary and Hospital.

In the literature on cases of so-called traumatic dislocation of the atlas cases are often met with which occurred following banal traumata. In the opinion of the writer such trivial violence cannot be the main cause of the dislocation of the atlas. These cases should therefore be classified as spontaneous.

To those cases in which the force described was not sufficient to be regarded as being the main cause of dislocation of the atlas the following cases described in the literature as being of traumatic origin should be added: 1 case without known trauma (MIXTER & OSGOOD 1910); 1 case which occurred while the patient was throwing a ball (OGILVY 1915); 7 cases, of which 5 occurred in children in association with acute fever and without any known trauma and 2 during treatment by cultists (BROOKES 1935) as well as 2 cases described by BLAINE (1925); 2 cases which occurred on movement of the head (SUDECK 1923, 1 case, and RANKIN 1936, 1 case); 2 cases, one described by LEDENT (1925) and the other by ROBERTS (1927), in which the dislocation occurred after operation on the upper respiratory tract under anesthesia and finally 1 case occurring during play (BLOUNT 1954).

Finally, a further 6 cases of spontaneous dislocation of the atlas have been described in recent years and therefore not included in the above mentioned compilations (LOUNAVAARA 1949, KORNBLUM et al. 1952, GROGONO 1954, and KOTSCHER 1955).

Cases of dislocation of the atlas in the absence of fracture described in the literature but not included in the above mentioned compilations are given in Table V.

TABLE V.

Author	Year	Without trauma	Slight trauma	Severe or undefined trauma
Bell	1830	1	1	
Malgaigne	1855	2		
Hesse	1896			1
Corner	1907			11
Mixter & Osgood	1910		1	
Ogilvy	1915		1	
Sudeck	1923		1	
Blaine	1925		2	
Ledent	1927		1	
Königweiser	1928			3
Garnier & Delon	1930	1		
Greeley	1930			1
Lob	1930	1		
Coutts	1934	21		
Brookes	1935		7	
Hudson	1935			4
Roberts	1937		1	
Rankin	1938		1	8
Lounavaara	1949	1		
Jackson	1950			1
Kornblum et al.	1952	2		
Blount	1954		1	
Grogono	1954	2		
Kotscher	1955	1		
Total		32	17	29

The literature surely contains still more cases of dislocation of the atlas not combined with fracture. In the less recent literature it appears that most of the cases of spontaneous dislocation of the atlas are concealed under other diagnoses (GRISEL 1930, BLUNCK 1935). In addition in many of the old reports the cases are not described in sufficient detail to decide with certainty whether they should really be classified as dislocation of the atlas.

The first column in Table V comprises cases of spontaneous dislocation of the atlas not included in earlier compilations. The second column includes cases in which the trauma sustained was too slight reasonably to be of any etiologic importance. If these cases be included among the so-called spontaneous dislocations of the atlas, the sum including those described in the earlier literature (SULLIVAN, BOEVER & HENNEBERT) will be 176 (Table VI).

TABLE VI.

	Without trauma	Slight trauma	Severe or undefined trauma	Total
From collections of SULLIVAN and BOEVER & HENNEBERT	127			
Plus those in Table I	32	17	29	
Total	159	17	29	205
	159	46 (22.4 %)		205
	176		29 (14.1 %)	205

As to the remaining 29 cases, which represent 14.1 per cent of the 205 cases on record without combined fracture, the trauma sustained was often not described satisfactorily to judge whether it was slight or severe. Among these 29 cases the trauma was probably also sometimes slight. Even if it be supposed that these patients had sustained severe trauma, opinions still differ as to whether trauma by itself can lead to dislocation of the atlas without combined fracture. Some authors (MALGAIGNE, GREIG) state that such dislocation only occurs in patients with predisposing weakness of the ligaments. This would imply that in these remaining cases the trauma described should be a contributory factor, but not the only cause of dislocation of the atlas.

As suitable treatment WATSON-JONES (1955) recommended reposition under anesthesia and subsequent immobilisation in craniothoracic plaster for 10 weeks and then immobilisation with a detachable collar for a further 3 weeks. SULLIVAN is of the opinion that reposition ad modum WALTON (1893) is too risky in inexperienced hands and that this method does not give such satisfactory reposition as the use of permanent traction. According to SULLIVAN, the head should be dorsoflexed during traction treatment. Since traction treatment is to be continued for 2—4 weeks skeletal traction should be preferred. SULLIVAN therefore suggests especially in the presence of neurologic symptoms skeletal traction with Crutchfield's tongs for 2—3 weeks, after which reduction in SULLIVAN's cases was completed or could be completed by manipulation after which the head and the neck were immobilised in plaster or a collar.

GROGONO (1955) shared SULLIVAN's view. For cases that can be reduced, but which recur after traction treatment GROGONO suggested surgical fixation by fixing the posterior arch of the atlas to the spinal process of the epistropheus by cerclage. In such patients with threatening neurologic symptoms, quadriplegia, TITRUD et al. (1949) and MARGULIES et al. (1955) performed surgical decompression and subsequent fusion.

MALGAIGNE was of the opinion that pathologic dislocation of the atlas always resulted in osseous ankylosis.

BLUNCK and HESS et al. studied inveterate cases that had been diagnosed earlier but not treated. BLUNCK described a case examined 18 months later and which showed clinical and roentgenographic improvement with only slight persistent torticollis and slight limitation or the range of mobility of the head. The other inveterate case described by BLUNCK had existed for 12 years, and in that case the dislocation persisted and turning of the head was considerably limited. BLUNCK concludes that spontaneous healing may occur. HESS et al. also described a long-standing case (5 years) that had not been treated. The course resembled the second case described by BLUNCK.

If a case receives proper treatment, the prognosis is said to be favourable (WATSON-JONES, SULLIVAN, GROGONO). Also in those cases with neurologic symptoms the prognosis is good. Recovery after extensive paresis or quadriplegia has been described (GARNIER & DELON, WATSON-JONES, WILSON et al., TITRUD et al., MARGULIES et al.). BERKHEISER & SEIDLER described such a case in which paresis disappeared before the patient received treatment.

According to WATSON-JONES, the issue is seldom fatal. Of their 103 cases of spontaneous dislocation of the atlas BOEVER & HENNEBERT reported 6 deaths. In such cases death appears to be due to respiratory paralysis (BELL, RAMOND, APERT et al. 1928).

Chapter V

THE POSSIBLE SIGNIFICANCE OF TRAUMA IN DISLOCATION OF THE ATLAS

GREIG's opinion, which is based on examinations post mortem, that the transverse ligament of the atlas is normally stronger than its osseous attachments, has not been accepted by all. This has led to a divergence of opinion as to what should be understood as "spontaneous" dislocation of the atlas (WATSON-JONES, COUTTS, WILSON et al.), as is apparent from the varying definitions and suggestions on record (ODELBERG-JOHNSON, DELGOFFE, WILSON et al., BÖEVER & HENNEBERT). The scope of the term thus varies with the author's conception of the possible rôle played by trauma in the dislocation.

The resistence of the craniovertebral ligaments to longitudinal pull has been investigated by WOOD-JONES, who stressed that such violence could give rise to fracture of the base of the skull but never resulted in dislocation of the atlas. The resistance of the craniovertebral ligaments to violence perpendicular to the body has, however, not been studied. It was therefore considered desirable to investigate whether and to what extent such traumata play an etiologic rôle in dislocation of the atlas.

THEORETICAL BASIS OF THE INVESTIGATION

The investigation of the strength of the craniovertebral ligaments was based on postmortem examinations after fatal accidents in which either the head or the trunk had been exposed to massive force with consequent momentary change in its state of movement.

This change in state of movement can be brought about by the head or the trunk being abruptly stopped, deceleration, retardation or negative acceleration, or by the head or the trunk being momentarily brought into motion, positive acceleration. In both cases the connection between the head and the trunk is exposed to a strain. The resulting force per unit of mass or weight, *i. e.* the acceleration (a), can advantageously be expressed in multiples of acceleration due to gravity (G). It is directly proportional to the square of the rate of change in velocity and inversely proportional to the acceleration distance, *i. e.* length of braking or starting distance, according to the formula:

$$\frac{F}{m}=a=\frac{v_2{}^2-v_1{}^2}{2\cdot l}$$

where F is the constant force which changes the velocity (v) of a weight with a mass m from v_1 to v_2 along the distance l; the sign of F designates the type of acceleration. (In the formula both the rate of change in velocity and the acceleration distance may be infinitesimal, as on application of a sudden pull to a string fastened to a heavy weight with consequent rupture of the string. The formula holds as long as its quotient is finite).

If the distance of acceleration (l) is measured in metres and the speed in metres/sec. the acceleration will be expressed in m/sec^2. To obtain this in multiples of G, the value found must be divided by 10 (approximately).

If we imagine a person standing still ($v_1 = 0$) who is run into by a heavy vehicle and suppose that the force hits the trunk up to the level of the upper thoracic vertebra the neck will try to give the relatively heavy head the same speed as the rest of the body ($v_2 = v$). Even if a certain yieldability of the body must be supposed owing to some longitudinal yieldability of the cervical spine and to the yieldability of the trunk to force, starting distances as small as 5—20 cm are possible. A plane force against the back must imply a minimal acceleration distance, a similar force from in front or from the side of the chest must imply some elongation of the acceleration distance because of the yieldability of the wall of the chest.

In assessment of the force which under such circumstances is applied to the connection between the head or the neck, we may use the following example:

$$v = 36 \text{ km/hour} = 10 \text{ m/sec},$$
$$l = 0.1 \text{ m},$$

then a is 50 G, which implies a force of 50 kg per kilo of the weight of the head.

Reduction of the accleration distance by 50 per cent implies in accordance with what was said above a doubling of the effect of acceleration and a doubling of the same distance a 50 per cent reduction in the effect of acceleration which would then be on 0,05; 0,10 and 0,20 metres acceleration distance respectively 100, 50 and 25 G.

A doubling of the change in speed produces the fourfold increase on the effect of acceleration which at 72 km/hour, *i. e.* 20 m/sec, under otherwise similar conditions would be 400, 200 and 100 G, respectively.

This force is exerted during a short period $t = \frac{2 \cdot l}{v}$ which with an acceleration from 0—10 m/sec implies 0,01; 0,02 and 0,04 sec respectively and with an acceleration from 0—20 m/sec 0,005; 0,01 and 0,02 seconds, respectively, at 0,05; 0,10 and 0,20 meters acceleration distance.

It should, however, be observed that the acceleration cannot be supposed to be constant, for which reason the figures given for the effect of acceleration are only a mean. The maximal value is thus larger during a shorter period.

In traffic accidents of the above mentioned type there are thus wide possibilities of the craniovertebral ligaments being exposed to severe strain. The direction of such strain will vary with posture and direction of the blow. This must be borne in mind in an investigation of the possibilities of the ligaments being ruptured by certain directions of strain.

MATERIAL

In these examinations the Director of the Department of Forensic Medicine in Lund was kind enough to place material at my disposal. This material was considered particularly suitable because examinations after such accidents are carried out not only to determine the cause of death but also to assist in reconstruction of the accident.

During the period October 1953 to January 1955 cranio-vertebral joint preparations from accidents of the above mentioned type, altogether 5 cases, were placed at my disposal for further study (Cases 24—28 in Table VII), which, however, revealed no damage not noted in the protocols.

In addition a number of protocols from earlier postmortem examinations of the same type were analysed.

Examination of the material offered details of interest and was therefore considered to merit an account. The material available consisted of 12 cases from the years 1933—1943 and 11 from the years 1950—1953 plus the 5 mentioned above.

RESULTS

The 28 cases studied are accounted for in Table VII. Only injuries due to acceleration violence are considered. The most important types of injuries may be summarized as follows:

1. Skull fracture (ring fracture around the occipital foramen; see Fig. 30) 5
2. Occipital condyle fracture, bilateral 2
3. Occipital condyle fracture, unilateral, and rupture of the alar ligament on the other side 2
4. Fracture of the attachment of the alar ligaments on the dens 1
5. Fracture of the dens 3
6. Cervical vertebral fracture or rupture of the intervertebral discs (C_3—Th_1) 15

In 28 cases of trauma in which the ligaments of the craniovertebral joints were exposed to acceleration violence, the cranium or the cervical spine had been fractured.

In 15 of these cases fractures of the vertebral bodies or ruptures of intervertebral discs were the only acceleration injuries noted (under 6 above).

TABLE VII.

No.	Obd.-date	Age in years	Sex	Posture, type of violence and direction	Injury
1	6.9.33	29	M	Against trunk, sitting. Motorcycle from behind (right side).	Fractura C2—C3—C4 et C7—Th1.
2	14.11.33	44	M	Against trunk, walking. Car from behind (left side).	Fractura dens epistrophei et fractura C6.
3	30.8.38	6	M	Against trunk, walking. Car from behind (right).	Fract. dens epistroph. c. luxat. atlant. et fract. C7—Th1.
4	6.12.38	69	M	Against trunk, cycling. Lorry from behind.	Fractura C6—C7.
5	6.6.39	28	M	Against trunk, cycling. Car from behind.	Right occipital condyle fractured. Anterior arch of atlas fractured. Upper fragment fastened in membrana atlantooccipitalis anterior, lower fragment in membrana atlantoepistrophica anterior. Other ligaments torn suboccipitally.
6	15.8.39	8	M	Against trunk, walking. Car from right.	Both occipital condyles avulsed. All ligaments with attachment on anterior margin of the os foramen magnum torn.
7	11.10.39	40	M	Against trunk, cycling. Car from left.	Fractura C7—Th1.
8	25.1.40	14	M	Against trunk, cycling. Lorry from behind (left).	Fractura C3—C4.
9	31.1.40	30	M	Against trunk, walking. Lorry from behind.	Fractura C3—C4.
10	3.8.40	56	M	Against trunk, walking. Car from left.	Fractura C6—C7.
11	23.2.43	68	M	Against back of head. 80 kg sack. Fall 8—9 m.	Fractura C4—C5.
12	11.7.50	66	M	Against trunk, walking. Car from in front.	Fractura C5—C6.
13	11.8.50	4	M	Against trunk, walking. Car from right.	Fractura C4—C5.

14	16.11.50	62	M	Against trunk, cycling. Car from behind.	Fractura cranii. Ring-fracture: sphenoidale-temporalia-occipitale.
15	3.3.51	71	M	Against trunk, walking. Car from behind.	Fractura C7—Th1.
16	9.4.51	64	F	Against trunk, walking. Car from in front.	Fractura C5—C6.
17	13.6.51	41	M	Against trunk, sitting. Car from behind.	Fractura C3—C4.
18	1.12.51	76	M	Against trunk, walking. Car from in front.	Fractura C6—C7.
19	13.12.51	20	K	Against trunk, walking. Car from behind.	Fractura baseos dentis.
20	29.12.51	22	M	Against trunk, walking. Car from behind.	Fractura cranii. Ring-fracture: sphenoidale-temporalia-parietalia.
21	12.3.52	30	M	Against trunk, walking. Train from in front (right).	Fractura cranii. Ring-fracture: sphenoidale-temporalia-parietalia.
22	3.12.52	62	M	Against trunk, walking. Car from left.	Fractura C3—C4.
23	4.8.52	35	M	Against chin. Drove into ditch with mc.	Fractura cranii. Ring-fracture: sphenoidale-temporalia-parietalia.
24	22.10.52	31	M	Against trunk, walking. Car from behind.	Right occipital condyle fractured. Left alar ligament torn. Atlas fracture.
25	7.1.54	57	M	Against trunk, cycling. Car from left.	Fractura cranii. Ring-fracture round os occipitale magnum.
26	3.11.54	3	K	Against trunk, walking. Car from left.	Attachments of alar lig. on dens fractured, fixed to alar lig. Membr. tect. avulsed. Transverse lig. intact.
27	19.11.54	43	M	Against trunk, walking. Car from left.	Avulsion of both occipital condyles.
28	20.1.55	35	M	Against forehead. Motorcycle against machine axle.	Fractura C3—C4.

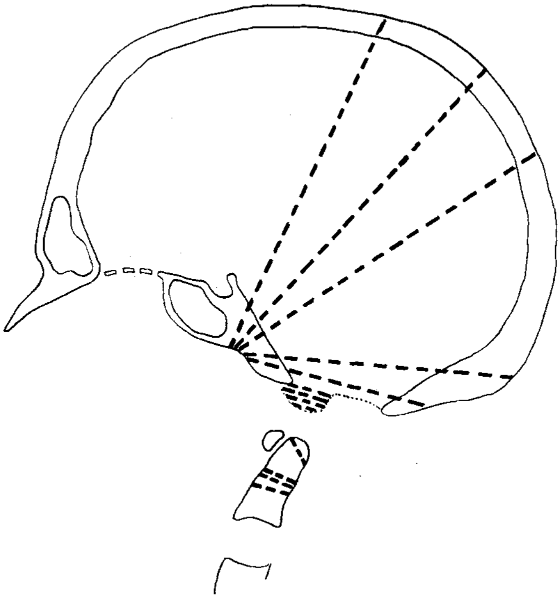


Fig. 30.

In the remaining 13 cases (1—5 above) the indirect violence resulted in fractures of the cranium or the dens (see Fig. 30). In 2 of these cases (under 3 above) a combination was seen of occipital condyle fracture on one side and rupture of the alar ligament on the other.

In no cases had the ligaments ruptured in the absence of skeletal injury.

DISCUSSION

If the craniovertebral ligaments were, as is widely believed, a locus minoris resistentiae, rupture of the craniovertebral ligaments should be a common cause of death in traffic accidents, and consequently well known in forensic medicine. But this is not so: on the contrary some specialists in forensic medicine and pathologists appear to be of the opinion that these ligaments normally are so strong that dislocation of the atlas cannot occur unless the atlas or the dens is fractured (ORFILA, GREIG). Avulsion fractures in the region of the craniovertebral joints have been described (HJ. SJÖVALL 1943) but it appears that no investigations have been made with the intention to elucidate the strength of the craniovertebral ligaments on exposure to violence in directions other than longitudinal.

Acceleration violence usually occurs while the subject is upright, standing or walking or sitting. The violence is then usually horizontal, *i. e.* perpendicular to the spine. An investigation of the craniovertebral ligaments of subjects who had died from acceleration injuries in the region of the craniovertebral ligaments was therefore considered desirable as a supplement to those earlier investigations of the effect of violent extension only (WOOD-JONES).

Preparations from 5 cases (Nos. 24—28 in the Table VII) were studied. In none was atlas dislocation seen, in none was the transverse ligament ruptured, nor was any rupture of the craniovertebral ligaments seen in the absence of fractures.

In an attempt to find a wider basis for any subsequent conclusions, a further 23 protocols from autopsies in wich death had been due to acceleration injuries were analysed. Although the pathologist had not been directly on the watch for ruptures of the craniovertebral ligaments, it is doubtful whether any such ruptures were missed, because blood in the tissues in the region of the foramen occipitale magnum or dislocations of the craniovertebral joints would most likely have revealed them on examination of the injuries mentioned above. If this was not the case there is, however, enough reason to summarize the recorded injuries since they are in themselves informative. Their occurrence requires either a counter-pull on the part of the craniovertebral ligaments, *e. g.* when a violence against the trunk gives rise to a cervical vertebral fracture, or a transmission of the force via the craniovertebral ligaments, *e. g.* when a violence against the trunk gives rise to a fracture of the cranium. In both cases the craniovertebral ligaments manifest a strength exceeding the force producing the injury.

Since ruptured ligaments were seen only in the presence of fractures, it may be assumed that the ruptures were secondary to the fractures and due to a consequent pull in a direction deviating from the normal longitudinal direction of the fibres.

Cranial fractures are of particular interest since the sequence of events is probably analogous with that of longitudinal fractures of the base of the skull as described in subauricular hanging (WOOD-JONES).

It was also of interest to note that cranial fractures of analogous type can occur following a blow against the chin (Case 23) or against the trunk (Cases 14, 20, 21, and 25).

The observations made in this investigations confirm the opinion expressed by GREIG that the craniovertebral ligaments do not rupture under otherwise normal conditions.

The investigation also confirmed that the craniovertebral ligaments tolerate a violence sufficient to fracture the base of the skull (WOOD-JONES).

The investigation also supplemented WOOD-JONES observations in that it was shown that such injury can result from violence other than extension.

Chapter VI

PERSONAL CASES

Case 1. — The patient was a girl, aged 4 (born 4 April 1949). She had hitherto felt well. No trauma was known.

One day in May 1952, the girl was then 3 years old, she accompanied her parents on a boat trip. Nothing remarkable happened that day.

The following day the parents noticed that the gird held her head somewhat to the right, she had pain on the left side of the neck and did not want to run or walk quickly. She had no pain elsewhere, no cough or cold and her temperature was normal.

On medical examination 14 days later the tonsils were found to be enlarged.

Since neck-stiffness and pain persisted the girl was reexamined repeatedly and a presumptive diagnosis of arthritis of the suboccipital joints was made. In July 1952 chronic uveitis supervened.

From June 1952 until March 1953 the craniovertebral region was examined roentgenographically on nine occasions at three hospitals. On no occasion were any signs of a pathologic condition observed.

On otologic consultation a slight forward projection of the posterior pharyngeal wall had been observed. The cause of this was apparently not investigated.

A picture of rheumatic polyarthritis gradually developed. The patient was then referred to the Department of Rheumatology, University Hospital, Lund, whence she was referred in March 1953 to the Orthopedic Outpatient Department for investigation because of the painful malposition of the head.

On examination the patient was found to have torticollis with the head turned to the left and tilted to the right and

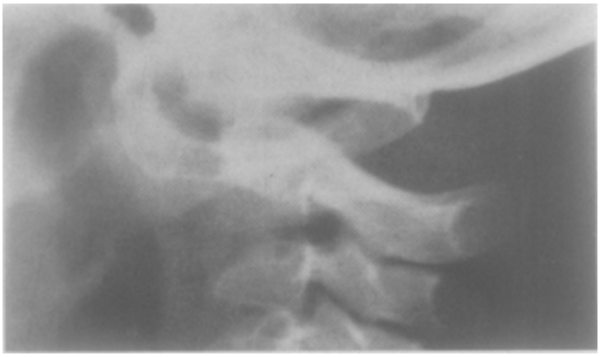


Fig. 31.

anteflected. She walked carefully as if she were trying to balance her head. She supported her head with both hands on change of posture. Muscle contraction and pronounced tenderness in the upper dorsal region of the neck were noted. Roentgen examination now revealed considerable dislocation of the atlas (Fig. 31).

The patient was treated with traction and immobilisation until February 1954. She then felt well. The position of the head was still slightly abnormal. The range of turning the head to the right was markedly decreased and the atlas was still somewhat dislocated (Figs. 32 A—B).

Exacerbations of the rheumatic disease had resulted in total stiffness of the entire cervical spine when seen at examination in August 1955.

Case 2. — The patient was a girl aged 8 (born 5 September 1944).

She had had polyarthritis since December 1950 and had been cared for in various hospitals since September 1951.

One of the first days in June 1952 she got a torticollis. On attempt to correct the displacement, the patient cried and complained of pains in the neck.

Roentgen examination of the cervical spine in June and August 1952 revealed nothing of interest.

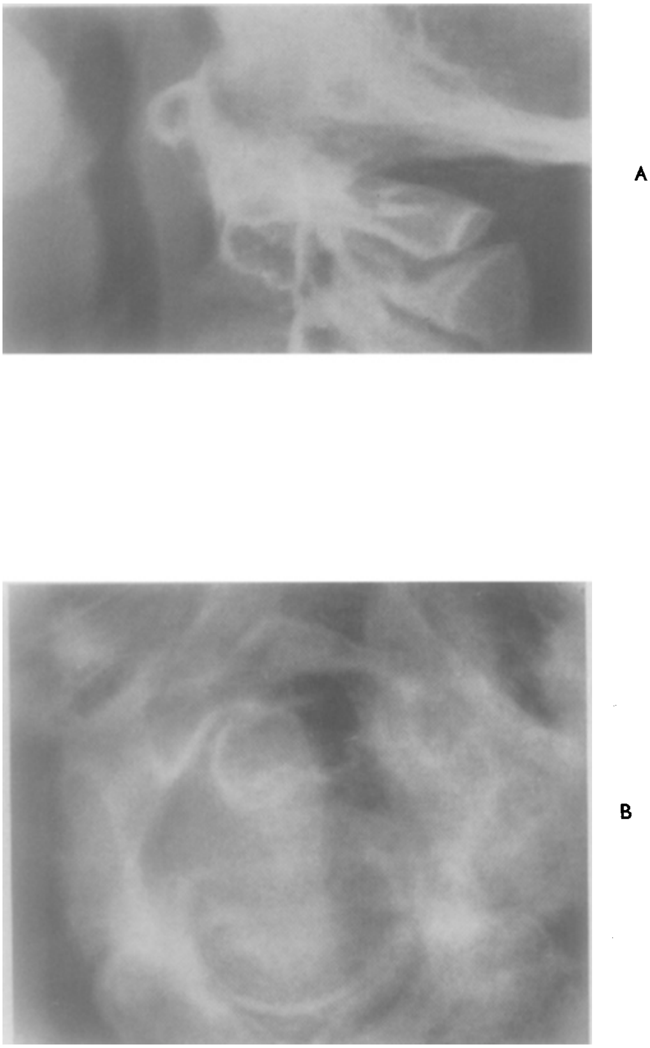
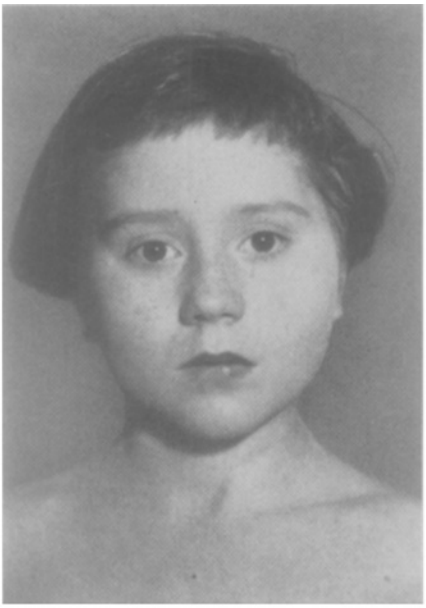


Fig. 32.

Case 1—4 were published earlier (Werne, S.: Spontaneous Atlas Dislocation. Acta Orth. Scand. 25: 32—43, 1955).

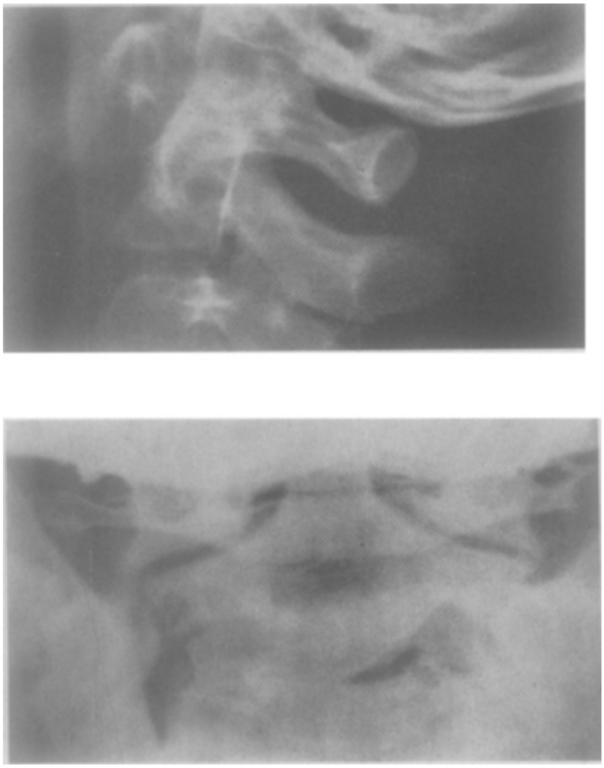


A

B

C

Fig. 33.



A

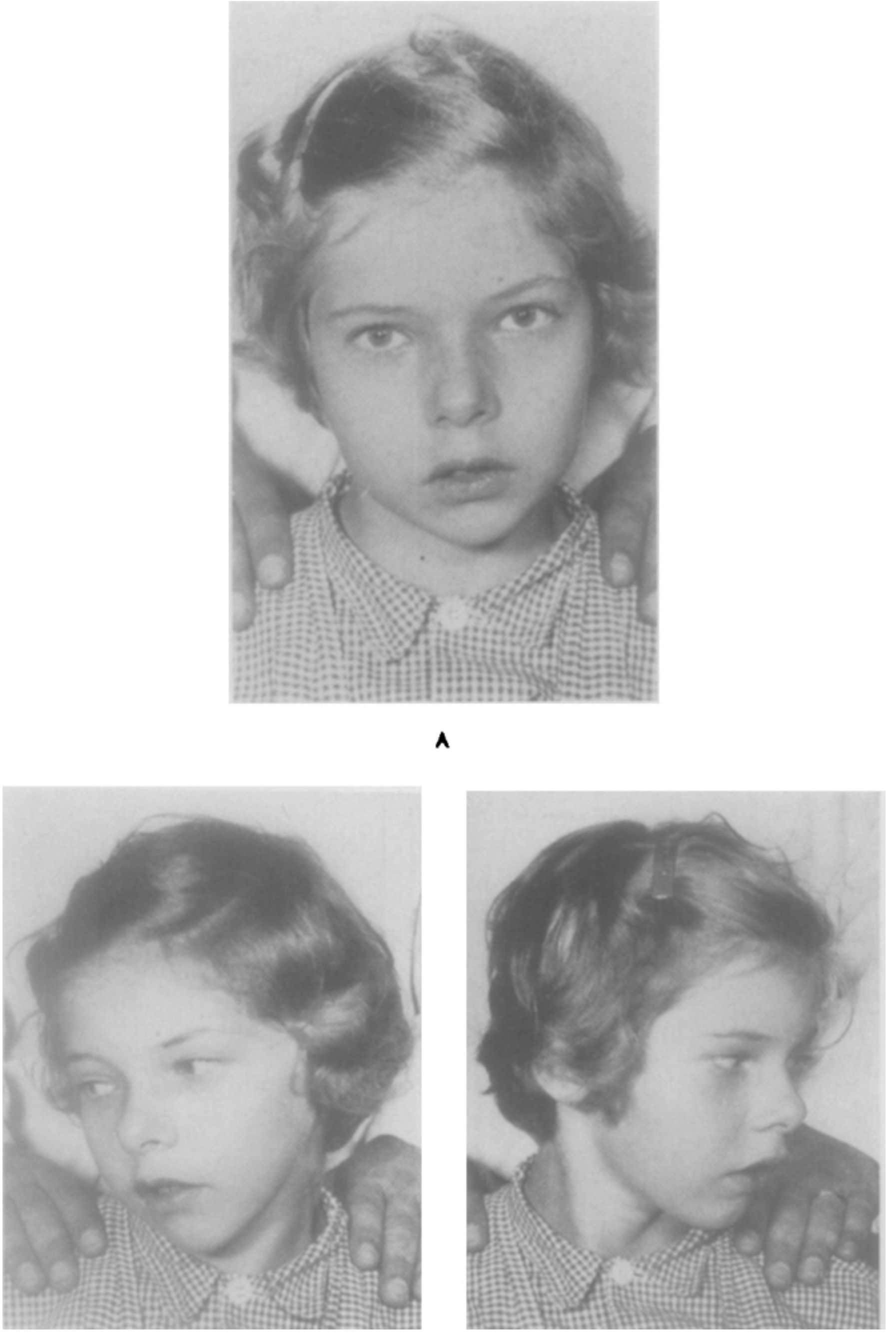
B

Fig. 34.

In March 1953 the patient was transferred to another hospital and at that time her neck was giving her no trouble except that she was afraid to turn it sharply.

In March 1954 the patient was referred to the Orthopedic Department, Lund, for treatment of flexion contractures in both knee-joints and on examination there, dislocation of the atlas was discovered. Turning of the head to the right was markedly limited, but she had no other complains from the cervical region.

Examination revealed slight torticollis with the head turned to the left and tilted to the right (Fig. 33 A). She was only able



A

B

C

Fig. 35.

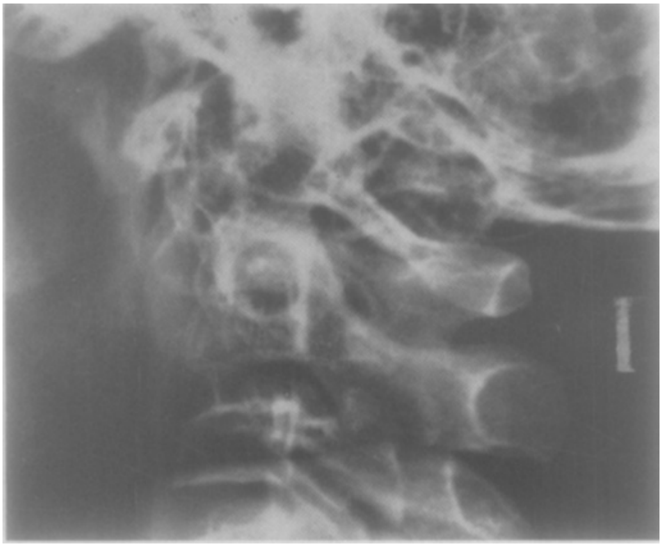


Fig. 36.

to turn the head slightly to the right (Fig. 33 B) but she could turn the head to the left to an almost normal extent (Fig. 33 C).

Roentgen examination showed dislocation of the atlas forwards (Figs. 34 A—B). Two months traction treatment failed to produce any demonstrable effect.

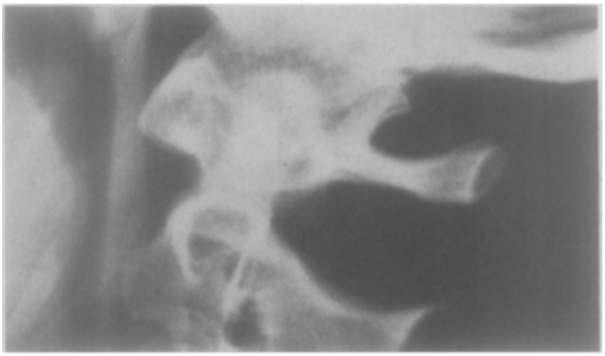
Case 3. — The patient was a girl aged 13 (born 1 May 1941). She had had polyarthritis since the age of 1 year. Slight tilting of the head had first been observed 1949 or 1950.

Her only persistent complaint was the displacement of the head and her inability to turn her head to the right.

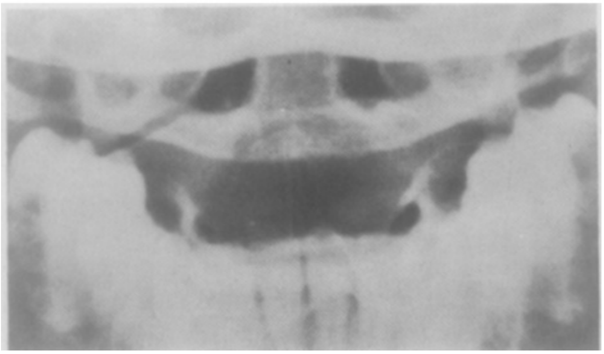
On examination in April 1954 the child was found to have a mild torticollis with the head turned to the left and tilted to the right (Fig. 35 A). Turning the head to the right was markedly limited (Fig. 35 B).

Roentgen examination showed dislocation of the atlas forwards (Fig. 36).

Case 4. — The patient was a girl aged 11 (born 7 November 1942).



A



B

Fig. 37.

She had had polyarthritis since the age of 5 years. Since 1953 she had found it difficult to turn the head to full extent. Apart from decreased range of turning of the head to the right she had no complaints.

Roentgen examination in April 1954 revealed moderate decalcification of the cervical vertebrae and an osseous ankylosis between the 2nd, 3rd, and 4th cervical vertebrae.

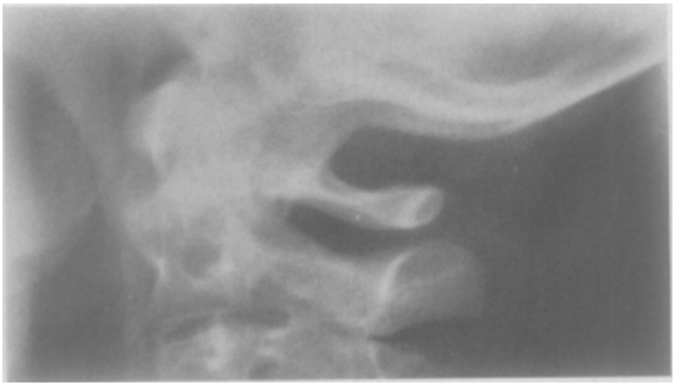


Fig. 38.

On examination in July 1954 the girl was found to have torticollis with the head turned to the right and tilted to the left.

Roentgen examination showed the left lateral condyle of the atlas dislocated forwards (Figs. 37 A—B).

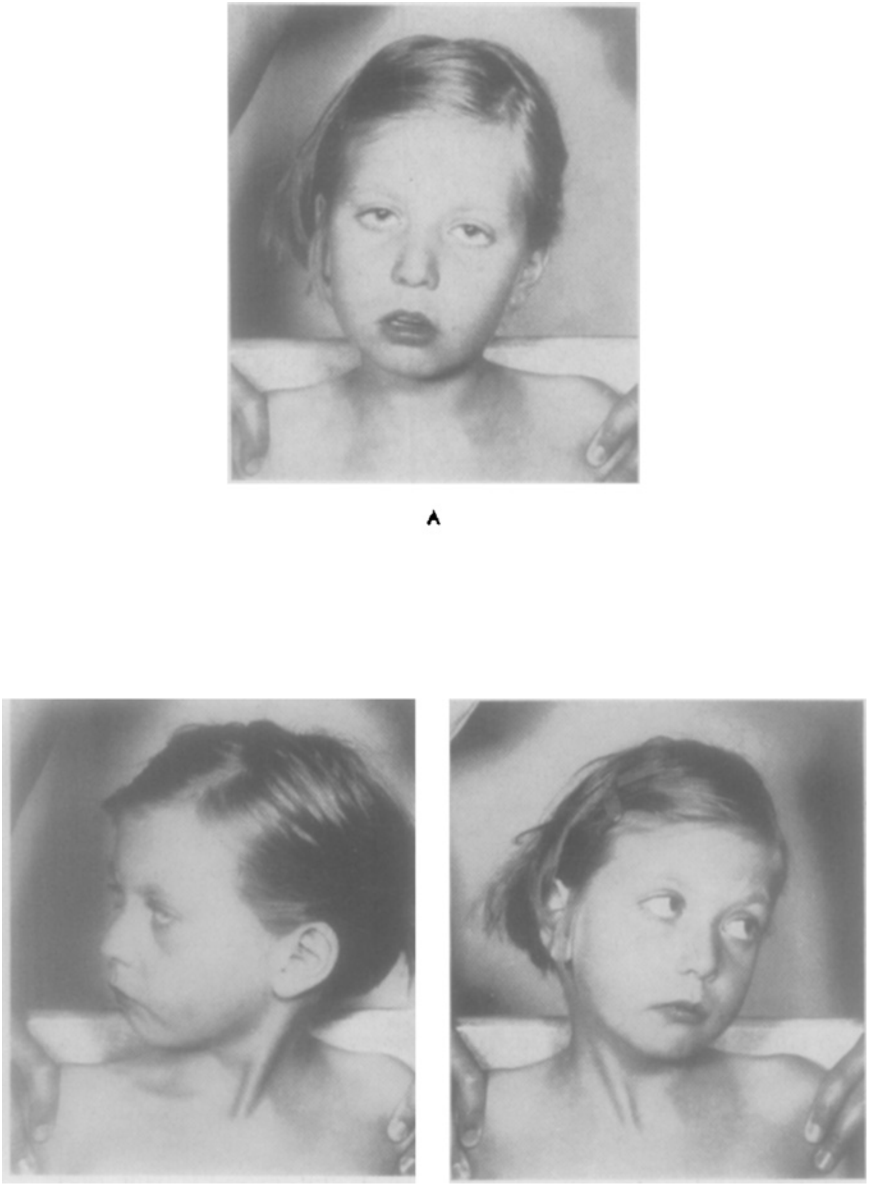
Case 5. — The patient was a girl aged 9 (born 8 August 1946).

She had had a unilateral gonitis from June 1951 until January 1952. She was then cared for in the Orthopedic Department, Lund, and microscopic examination of a biopsy specimen on 10 December 1951 showed non-specific chronic arthritis.

She then felt well until the spring of 1955. In March or April the parents noticed that the girl held the head slightly tilted to the left.

On examination at the Orthopedic Outpatient Department on 6 July 1955 torticollis was observed without affection of the sternocleidomastoid musculature and without facial asymmetry. Roentgen examination showed no signs of a pathologic condition (Fig. 38).

Since no improvement was observed during the following 14 days the patient was referred to the Orthopedic Clinic for investigation. Ophthalmologic, otologic and neurologic con-



A

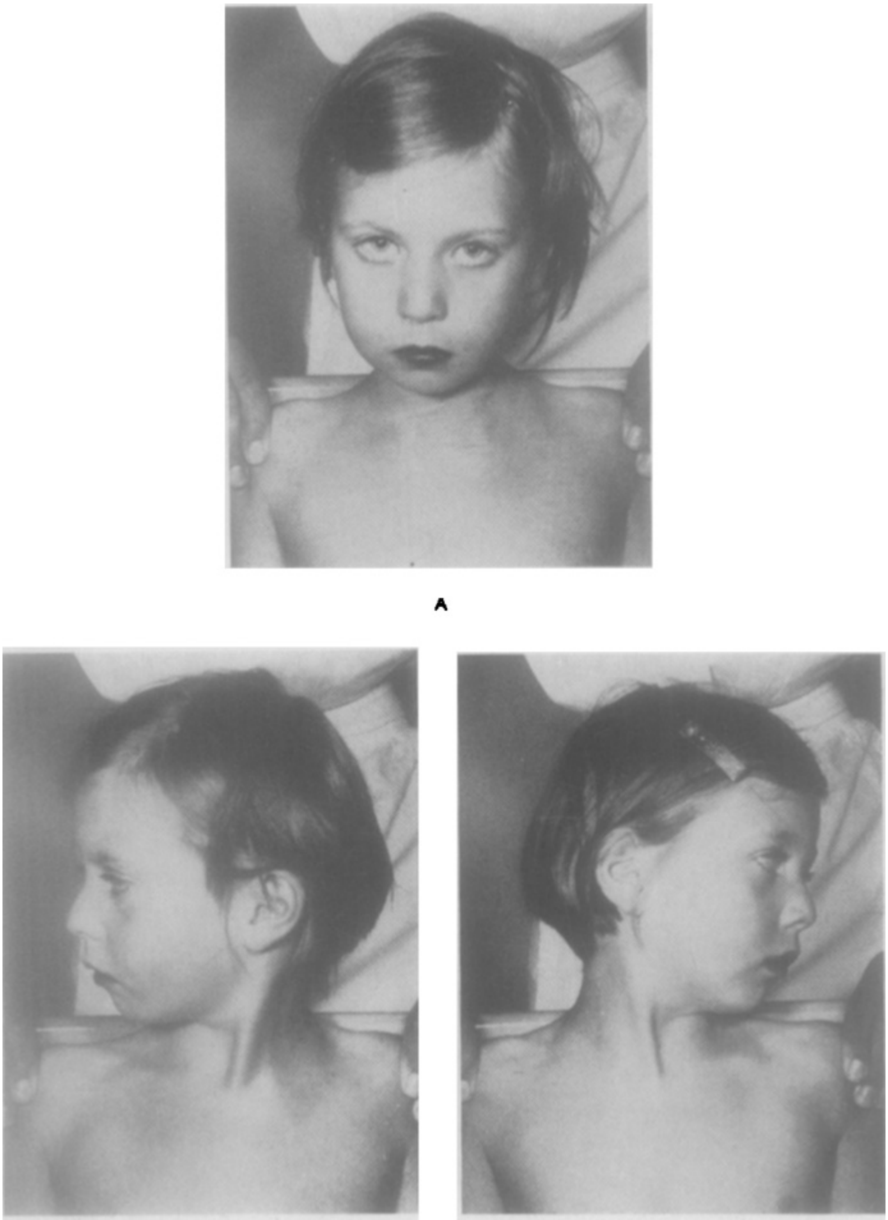
B C

Fig. 39.

Fig. 40.

sultation revealed nothing of interest. On 22 July 1955 the patient still had typical torticollis with the head turned to the right and tilted to the left (Fig. 39 A). Range of movement of the head to the right was not limited (Fig. 39 B), but she could only turn the head to a certain extent to the left (Fig. 39 C). The external protuberance of the occipital bone was displaced to the left relative to a line between the spinal processes of the cervical vertebrae: a dislocation of the atlas was therefore presumed. Since roentgen examination had hitherto failed to show any signs of a pathologic condition, radiographs were now taken in axial projection. These axial radiographs revealed a lateral displacement of the odontoid process in the atlas ring (Fig. 40).

The patient was treated with traction in Glisson's sling and examination 10 days later showed that the torticollis had disappeared, the external protuberance of the occipital bone was now in normal position and the patient was now able to turn the head almost to a normal extent (Figs. 41 A—C). Roentgeno-



A

B C

Fig. 41.

Fig. 42.

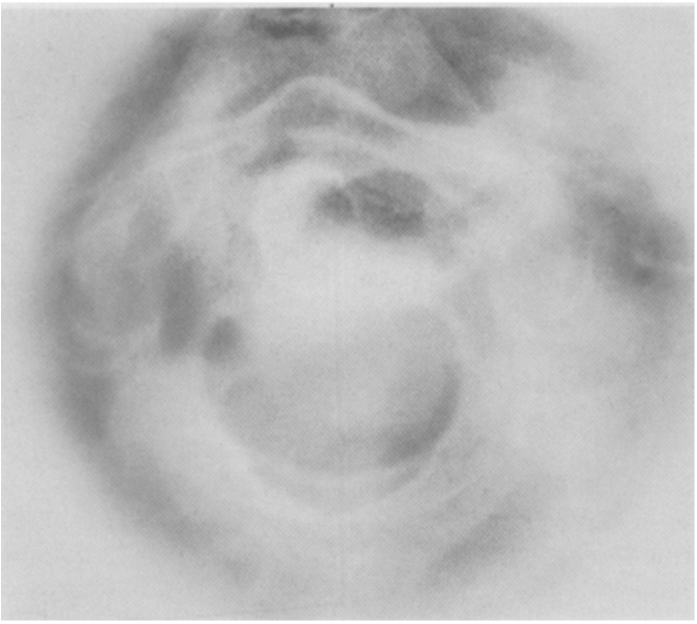
graphy showed that the odontoid process was now in a normal position in the atlas ring (Fig. 42).

The patient was then discharged but returned one month later to the Orthopedic Outpatient Department where the father reported that torticollis had recurred on a couple of occasions but disappeared again spontaneously. Examination revealed no torticollis, and range of movement of the head appeared to be normal. The patient was, however, treated with craniothoracal plaster. On removal of the plaster after 8 weeks, however, the patient had torticollis of the same type as before, which had apparently developed while the neck had been immobilised in plaster.

During the following 14 days the torticollis gradually disappeared spontaneously and when seen again 1 month after removal of the plaster in December 1955 the only pathologic finding was a slight limitation of left rotation of the cervical spine.

Follow-up examination on 24 July 1956 showed no further changes. Roentgen examination now showed a persistent slight

A



B

Fig. 43.

lateral displacement of the odontoid process in the ring of the atlas.

Case 6. — The patient was a man aged 39 (born 20 November 1916).

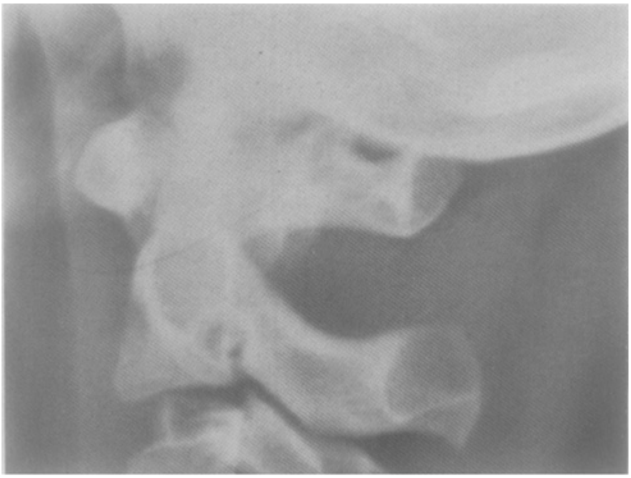
He had angina in October 1955. He had on that occasion a stabbing pain in the back of the neck to which he had, however, attached no importance. Since then, however, the cervical spine had been tender.

About Christmas-time 1955 the patient had another attack of angina. Now pain in the back of the neck was more severe than before. He consulted a general practitioner. The neck pain, however, persisted and occasionally he had paresthesiae in both arms.

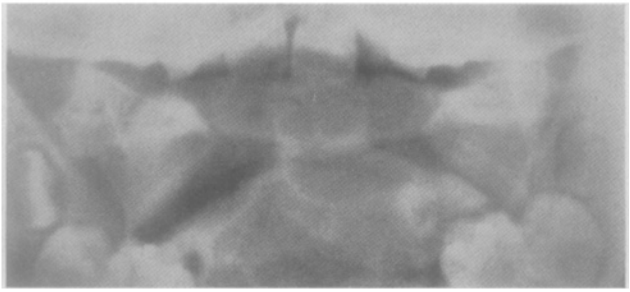
On examination at the Orthopedic Outpatient Department on 6 March 1956 he was found to have slight torticollis without affection of the sternocleidomastoid musculature. The right paravertebral musculature of the neck was contracted bridging the cervical lordosis in such a way as to convey the impression that the muscles of the left of the neck were missing. The external protuberance of the occipital bone was displaced to the left of the spinal process of the epistropheus. Reflexes were normal and no pareses were demonstrable.

Roentgen examination: frontal and lateral radiographs gave no information of interest. Axial radiographs, however, showed a lateral displacement of the dens in the atlas ring (Fig. 43 B).

The patient definitely refused hospital treatment and immobilisation in plaster and was therefore treated with a padded bandage which was renewed every third week from 6 March 1956 until 5 June 1956. Already within 3 weeks the patient reported that he felt better in that the paresthesiae had disappeared as well as a feeling of looseness of the head. He had noticed that the paresthesiae tended to return during sleep. When he noticed such paresthesiae he had let the back of his head hang over the end of the bedstead and thus curtailed the symptoms, since he was aware of the fact that immobilisation with a padded bandage was by no means perfect and since he was informed about the mechanics of the dislocation.



A



B

Fig. 44.

On 5 July 1956, when the patient returned to work he felt well. Range of mobility of the cervical vertebrae appeared to be normal. Palpation revealed no displacement and the patient showed no signs of muscle contracture. The region of the neck was of normal outline. Roentgen examination, however, revealed a slight lateral displacement of the odontoid process of the epistropheus in the atlas ring.

C
Fig. 44.

Case 7. — The patient was a boy aged 10 (born 29 April 1946).

He had had a cold for about a week, when while playing another boy gripped his head. He reported that this had caused no pain.

During the following lesson the back of the neck began to be painful. When he returned home after school he told his parents what had happened. The following day the pain increased and the parents noticed that the boy held the head tilted. Two days later on 14 April 1956, he was examined at the Orthopedic Outpatient Department in Lund where torticollis was observed with the head turned to the right and tilted to the left. The muscles on the right side were slightly tender. The external protuberance of the occipital bone was palpated 2—3 cm to the left of a line between the cervical spinal processes.

Roentgen examination verified the diagnosis as a dislocation of the atlas forwards (Fig. 44).

He received traction treatment for 3 weeks and then a cranio-thoracal plaster for a further six weeks. Roentgen examination afterwards showed no change in the dislocation.

He was then treated with immobilisation for a further 2 months.

When discharged on 10 July 1956 range of movement of the head was not limited, the head was no longer tilted and the patient felt well. However, roentgen examination showed no change in the dislocation.

DISCUSSION

ETIOLOGY AND PATHOGENESIS OF DISLOCATION OF THE ATLAS

Of the 7 cases of spontaneous dislocation of the atlas 4 could be dated to chronic polyarthritis (Nos. 1, 2, 3, and 4) and 2 to acute rhinopharyngitis (Nos. 6 and 7). This is in good agreement with JACOBS and COUTTS, who stated that chronic polyarthritis is a common cause of dislocation of the atlas and with GRISEL and WATSON-JONES who claimed that atlas dislocation often occurs in association with acute rhinopharyngitis. In one of the cases (No. 5) in which the parents did not seek medical advice until 3 months after the dislocation, they could not remember any previous or simultaneous disease. Three years earlier this patient had been treated for monarthritis, which was classified histo-pathologically as chronic non-specific arthritis. The possibility cannot be excluded that a similar disease had now affected the occipito-atlo-axoid joints. This assumption is strengthened by comparison with case 1 in which the initial symptom of a chronic polyarthritis was a dislocation of the atlas.

In case No. 7 the patient had had rhinopharyngitis for a week when he sustained a trauma while playing. Neck pain occurred during the subsequent hour and was soon followed by torticollis, which on examination 2 days later was found to be due to dislocation of the atlas.

The examinations described in chapter V, however, appear to support GREIG's conception that normally the occipito-atlo-axoid ligaments do not rupture on exposure to violence. This does not, however, exclude the possibility of trauma being a contributory causal factor. The term traumatic dislocation of the atlas, however, should not be applied to describe atlas dislocation not combined with fracture of the odontoid process of the epistropheus and/or atlas. Whether spontaneous atlas dislocation without fracture be referred to as spontaneous dislocation of the atlas or simply as dislocation of the atlas is immaterial provided it is realised that such a dislocation will never occur unless the transverse ligament is weakened.

Three theories have been advanced to explain the pathogenesis of spontaneous dislocation of the atlas (WITTEK, GRISEL, and GREIG).

An objection that may be raised against WITTEK's distension theory is that those parts of the capsule of the dorsal odontoid joint that are not covered by the transverse ligament consist of thin synovial membranes and therefore it is hardly possible to imagine an intraarticular pressure sufficient to produce distension of the strong transverse ligament.

For several reasons, including those given by GREIG, GRISEL's enucleation theory can hardly be valid. At any rate there can be no question of enucleating, since no change occurs in the relation between the base of the skull and the atlas.

GREIG's theory according to which dislocation of the atlas is due to hyperaemic decalcification of the osseous attachments of the transverse ligament appears at first glance to be an acceptable explanation provided that dislocation of the atlas, as stated by BELL, GREIG, and WATSON-JONES, is possible by insufficiency of the transverse ligament only. That an atlas dislocation can occur in insufficiency of the transverse ligament has been shown in the present investigation (pp. 60—62). Decalcification of the osseous attachments of the transverse ligament must, however, require a certain time and be so severe as to be roentgenologically demonstrable. But such decalcification is often not demonstrable in cases of spontaneous dislocation of the atlas (DELGOFFE).

Even if GREIG's statement be accepted that a roentgenologically demonstrable decalcification occurs within one week of an operation on a two month old fracture of the radius and even if it be assumed that decalcification not roentgenologically demonstrable had not occurred before then, there still remains in BOEVER & HENNEBERT's material 13 cases in which dislocation of the atlas occurred within one week of onset of a pre-disposing disease and cases are on record in which the dislocation occurred within one day of the onset (GRISEL, WATSON-JONES, SULLIVAN). In the cases described in the present material and in which the patients were examined roentgenographically soon after the dislocation had occurred (Nos. 1, 2, 5, 6, and 7) no decalcification was roentgenographically demonstrated.

It appears that as yet dislocation of the atlas can only be explained by the assumption of pre-disposing pathologic weakness of the transverse ligament. It is probable that various kinds of pathologic processes in the transverse ligament of its osseous attachments can favour spontaneous dislocation of the atlas. GREIG's theory therefore covers only part of the pathogenesis. Only histopathologic examinations of the transverse ligament and bone substance from the osseous attachments can clear up this point. In the present material none of the cases were fatal and therefore it was not possible to carry out any pathologic investigation.

MECHANISM OF DISLOCATION OF THE ATLAS

As mentioned earlier (page 90) some authors have classified dislocation of the atlas into different clinical types usually unilateral dislocation forwards, unilateral dislocation backwards, and bilateral dislocation forwards.

According to this classification, cases 1, 2, 3, 4, and 7 can be classified as unilateral dislocations forwards, while the remaining 2 cases (Nos. 5 and 6) showed no pathologic diastasis in the anterior odontoid joint and therefore should be classified as unilateral dislocations backwards.

A search of the literature failed to reveal any description of the mechanics of the types of atlas dislocation or any description of the occipito-atlo-axoid joints sufficient to throw light on the disturbance involved in dislocation of the atlas.

If conceptions of the types of dislocation are based on the works of MALGAIGNE, they appear to be founded on postmortem findings in earlier diagnosed cases of dislocation of the atlas. Here it might be objected that muscle tone ceases at death and the relation between the atlas and the epistropheus are then determined by external factors such as the position in which the head is supported etc. Therefore postmortem examinations of these joints permit no conclusions as to their position in vivo.

As shown earlier, the transverse ligament will not become totally insufficient unless it is entirely ruptured or weakened in its entire transverse section (pp. 60—62).

If this occurs the intervertebral joint surfaces of the atlas balance upon the convex joint surfaces of the axis. The odontoid process prevents dislocation backwards and the unaviodable consequence will be a dislocation forwards. The atlas glides over the anterior, forwardly declining epistropheal joint surfaces because of the absence of any ligamentary, musculary, skeletal or joint capsular support able to prevent such a movement, until the alar ligaments become taut and prevent further movement (Fig. 45 B).

Turning of the cranium from this starting position, *e. g.* to the left, implies that the right alar ligament will immediately wind around the odontoid process of the epistropheus and tighten up. The pull exerted by the alar ligaments first produces a sideward bending to the right in the occipito-atloid joint and secondly a translation of the atlas to the left in the atlo-axoid joints. If the translation of the atlas be ignored, the left condyle of the axis will on rotation describe a movement closely resembling that occurring on normal rotation of the atlo-axoid joint to the left. According to the degree of the primary dislocation forwards and the degree of rotation, the left condyle of the atlas will occupy a position before, in, or behind the normal midposition of the condyle, i. e., anteriorly, directly over or dorsally in relation to the corresponding parts of the articular surface of the epistropheus. Figs. 46 E, F, and G illustrates the rôle played by the degree of dislocation forwards,

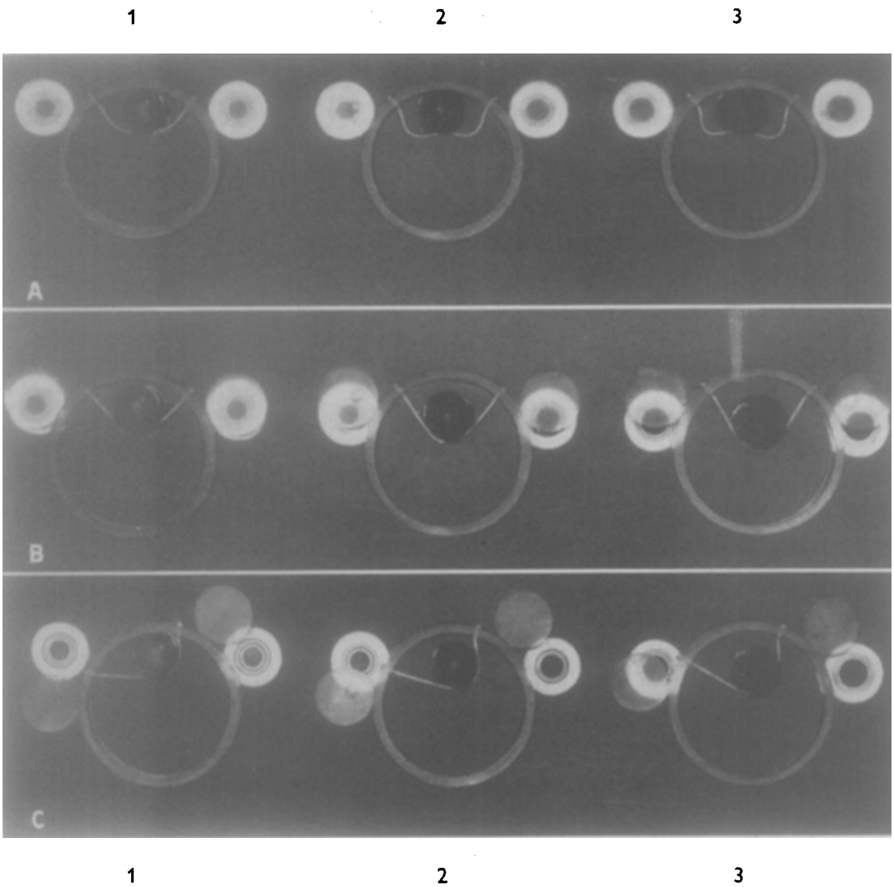
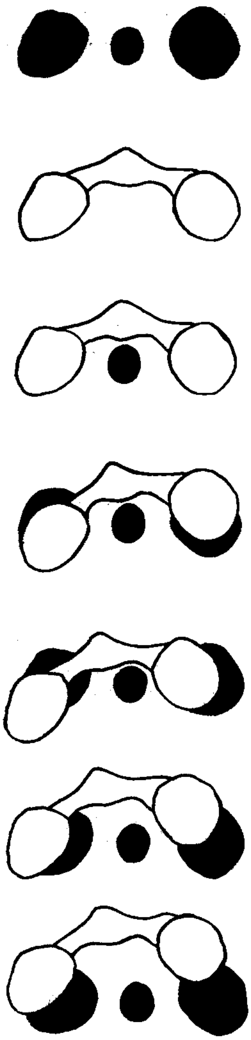


Fig. 45.

A. Illustrates normal midposition in the atlo-axoid joints. The silk threads illustrate varying slackness of the alar ligaments.

B. Illustrates primary bilateral atlas dislocation forwards. The lateral masses of the atlas are shifted forwards over the joint surfaces of epistropheus (white).

C. Illustrates torticollis positions on rotation to the left. The right alar ligament winds up around the dens (black).



A. Diagram of epistropheus, represented by the surface of the intervertebral joints and by a section through the collum dentis.

B. Diagram of atlas, represented by the anterior arch of the atlas and by the surfaces of the intervertebral joints.

C. Diagram of topography of the atlas and the epistropheus in midposition. The surfaces of the intervertebral joints cover each other.

D. Diagram of a normal rotational position between the atlas and the epistropheus.

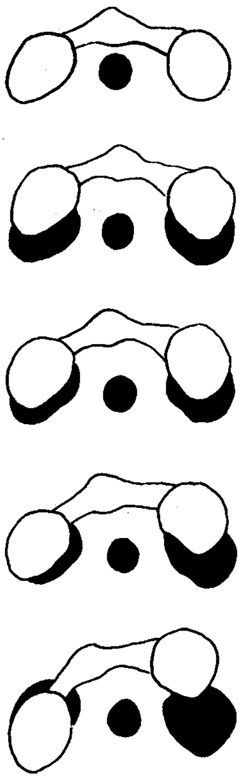
E. Diagram of so-called unilateral, left-sided dislocation backwards.

F. Diagram of so-called unilateral, right-sided dislocation forwards.

G. Diagram of so-called bilateral dislocation forwards.

Fig. 46.

Illustration of the rôle played by the dislocation forwards in the development of the so-called types of dislocation (E—G).



A. Diagram of relationship between the atlas and the epistropheus in midposition. The intervertebral joint surfaces cover each other.

B. Diagram of the primary phase of dislocation, so-called bilateral dislocation forwards.

C. Diagram of the dislocation on moderate rotation, so-called bilateral dislocation forwards.

D. Diagram of the dislocation on further rotation, so-called unilateral dislocation forwards.

E. Diagram of the dislocation on still further rotation, so-called unilateral dislocation forwards with contralateral dislocation backwards.

Fig. 47.

Illustrating the rôle played by the rotation in the development of the so-called types of dislocation (C—E).

Figs. 47 C, D, and E, the rôle played by the degree of rotation in the development of different types of dislocation.

If the primary dislocation forward is slight or moderate, it is possible for the alar ligaments to exert their inhibitary action on rotation by an ordinary or practically normal rotatory position of the atlas upon the axis. The possibility must therefore be considered that a dislocation thus can be reduced to a normal or practically normal rotatory joint position (Figs. 46 D and 45 C, 1). But fixation in the annulus osteofibrosis has ceased owing to the insufficiency of the transverse ligament.

The pull exerted by the alar ligaments on turning of the head can therefore produce a lateral displacement of the atlas whereby the backwardly rotating condyle of the atlas in relation to the forwardly rotating condyle will have a larger radius of movement and thereby perform larger excursions. A so called unilateral dislocation of the atlas backwards thereby occurs (Fig. 46 E).

If the primary dislocation of the atlas is pronounced, complete reposition or reduction of dislocation forwards cannot be expected on turning of the head (Figs. 45, 2—3). The necessary shortening of one of the alar ligaments would require too extensive a turning of the head to be possible. Such a turning of the head would also imply that one of the alar ligaments would again be slackened with resultant instability of the head since the checking effect is eliminated. Figs. 45 C, 2—3 show two positions of rotation to the left. In both cases they show maximal rotation at which he rein effect can be maintained by the alar ligaments represented in the figure by the strings. Further left rotation of the occipito-atloid unit represented by the plastic ring would result in slackening of the left alar ligament whereby the occipito-atloid unit would become instable. In pronounced primary dislocation of the atlas forwards, then, only partial reposition of the dislocation forwards can be expected on turning of the head and the final rotational position must reasonably lie within the limits of the maximal rotational position allowing the alar ligaments to maintain their checking effect. In these cases the result will be one of the types of dislocation illustrated in Figs. 46 E—G or 47 C—E.

In primary atlas dislocation forwards the odontoid process of the epistropheus encroaches upon the spinal canal. If the patient survives, primary dislocation forwards it is very probable that this dislocation will elicit a protective reflex with consequent torticollis because cranial rotation completely or partly reduces the dislocation forwards.

In those cases in which dislocation forwards completely disappears a certain lateral displacement of the atlas must be expected but it may be so slight as not to be demonstrable.

There are three explanations for the final torticollis position:

1) On small primary dislocation forwards the position might not be distinguished from normal rotation.

2) If the dislocation forwards is more severe, a corresponding higher degree of cranial rotation will be necessary before tension arises in the two alar ligaments. Lateral displacement of the atlas will be more pronounced and the alar ligaments will therefore retain a certain functional increase in length. The accompanying movement of the epistropheus will thereby be delayed which will manifest itself clinically by palpatory over-rotation of the cranium and atlas in relation to the spinal process of the epistropheus.

3) In those cases in which dislocation forwards persists the alar ligaments have not recovered their normal function, *i. e.* inhibition of rotation. The accompanying movement of the epistropheus is then absent and manifests itself by an over-rotation of the cranium and the atlas in relation to the epistropheal spinal process.

We thus have two main clinical alternatives:

1) *Cases in which primary dislocation forwards has been reduced,* which can be diagnosed by palpable over-rotation of the cranium and atlas in relation to the epistropheus. Roentgenologically only rotation in the atlo-axoid joints will be demonstrable with certainty. A lateral displacement of the dens in the atlas ring should be judged with great caution (see below).

2) *Cases with persistent dislocation forwards,* which can be diagnosed by palpation or by roentgenographically demonstrable dislocation forwards of the atlas and palpable over-rotation of the cranium in relation to the epistropheus.

In view of the observations made in the present investigation (p. 133), however, there appears to be reason to suspect the existence of a third alternative, namely that among those cases of acquired torticollis without demonstrable overrotation of the cranium in relation to the epistropheus there are a number of cases not diagnosed and which represent those in which the primary dislocation forwards was reduced or practically reduced with resultant normal type of rotation in the atlo-axoid joints.

It is thus apparent from the foregoing that there is no reason to distinguish different clinical types of dislocation on the basis of the position of the surfaces of the intervertebral joints. The underlying mechanism is probably one and the same throughout namely a primary bilateral dislocation forwards and a secondary rotation from this position.

ROENTGENAPPEARANCE OF DISLOCATION OF THE ATLAS

If the distance between the odontoid process of the epistropheus and the anterior arch of the atlas is abnormally large in roentgenograms a diagnosis of dislocation of the atlas is obvious.

On the basis of roentgen examinations of 50 adults and 20 children the upper limit of the normal minimal distance between the anterior arch of the atlas and the odontoid process of the epistropheus is given by JACKSON (1950), as 2.5 mm for adults and 3 mm for children. He claims, however, on the basis of a simultaneously published case that this limit for children chould be set higher, 4.5 mm in his case. However, the possibility cannot be excluded that in this case the increased distance was due to an earlier dislocation of the atlas (see p. 144).

In dislocation of the atlas frontal radiographs (sagittal projection) will usually show a decrease in hight of the intervertebral joint space between the epistropheus and the atlas and the side dislocated or no joint space at all owing to superimposition.

DELGOFFE (1934) showed that normal voluntary assumption of a position of torticollis will give the same type of roentgenogram.

Superimposition can, however, occur on lateroflexion (Fig. 28) as well as on rotation (Fig. 29) in the craniovertebral joints. It was shown earlier that these movements are interdependent (p. 47). The reason for this superimposition is that

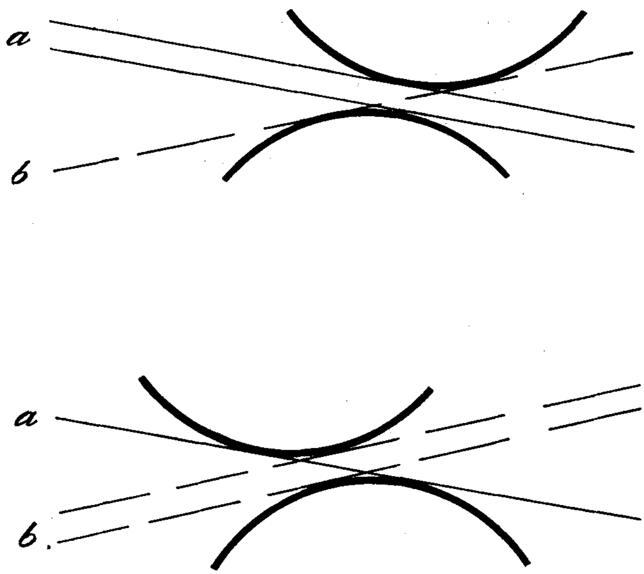


Fig. 48.

on rotation the two atlas condyles will be located on either side of the convexity of the condyles of the epistropheus.

A beam projecting the intervertebral joints freely on one side will therefore not show joint space or if so a reduced joint space on the other side and vice versa, a and b, respectively in Fig. 48.

Superimposition of either intervertebral joint between the atlas and the epistropheus in frontal roentgenograms will thus only show the existence of a rotational position between the atlas and the epistropheus.

In acute cases with painful contracture of the neck muscles it will be difficult to include axial radiograms in the roentgen examination. In addition high demands must be placed on the roentgenologist that the axial roentgenograms of the odontoid process of the epistropheus really are axial because only obliqueness would prevent evaluation of position of the odontoid process in the atlas ring. In addition, on turning of the head, the atlas and/or epistropheus probably move in varying planes. Rotation between these two vertebrae can thus make it impossible to obtain axial radiograms of both vertebrae in one and the same radiograph. Small lateral displacements can therefore not be judged in such roentgenograms.

Some investigators (BOEVER & HENNEBERT, JOSTES, KOTSCHER) claim that tomographic assessment of the height of the intervertebral atlo-axoid joint spaces should be resorted to in order to decide whether it is reduced in some layer or other. On rotation in the atlo-axoid joints, however, no landmarks are available for reference. If tomographic examination shows a pathologic reduction of the intervertebral joint space, there is reason to assume a pathologic condition involving the cartilage of the joint, but there is no reason to assume an atlas dislocation.

DIAGNOSIS OF THE DISLOCATIONS OF THE ATLAS

During the course of 3 years 7 cases of so-called spontaneous dislocation of the atlas have been seen at the University Hospital, Lund. Earlier only one case was described in this country under the diagnosis of "cervical spondylarthritis after tonsillectomy" (ODELBERG-JOHNSON 1932). This suggests that the disease was formerly to a certain extent missed.

Of the above-mentioned 7 cases 3 (Nos. 2, 3, and 4) had existed for 2 or several years and 3 (Nos. 1, 5, and 6) for 3 to 11 months before the diagnosis was made while one case (No. 7) was diagnosed within 1 week.

Delayed diagnosis as in case 1, 5, and 6 is in agreement with what may be read in the literature despite the fact that the diagnosis is generally regarded as simple (SWANBERG, SUDECK, BERKHEISER & SEIDLER, BROOKES, SULLIVAN, BOEVER & HENNEBERT, KOTSCHER). There is thus reason to suppose that a fair percentage of cases are missed. Therefore in sufficiently large clientels inveterate cases can surely be traced such as cases 2, 3, and 4 in the present material.

In acute or subacute cases the patients have torticollis with painful contracture of the neck-muscles while the sternocleidomastoid musculature is unaffected (WATSON-JONES). In the inveterate cases 2, 3, and 4 above persistant limitation of the range of turning the head was the only sequela.

As stressed earlier, the primary forward dislocation of the atlas can be spontaneously more or less reduced by the position of torticollis. In such cases in which the position of reduction agrees with a normal rotational position in the atlo-axoid joints it will not be possible to confirm the diagnosis by palpation or roentgen examination. In those cases in which reposition of the primary forward dislocation occurred by a somewhat increased rotation in the atlo-axoid joint such as in cases 5 and 6 above the dislocation is demonstrable in that spinal process of the epistropheus as in other demonstrable variations of the dislocation of the atlas — is displaced in relation to the external occipital protuberance in the same direction as the chin. In the evaluation of the above-mentioned finding possibility of anatomical variations must of course be recollected.

TREATMENT OF DISLOCATION OF THE ATLAS

Reposition under anesthesia and immobilisation in cranio-thoracal plaster has been suggested by WATSON-JONES. If plaster is to be understood as true immobilisation in reduced position the question of the effectivity of the fixation is related to the question of an effective fixation of the cranium and atlas on one hand and the epistropheus on the other. Only on maximal backward bending of the entire cervical spine will it be possible to immobilise the epistropheus. This would mean that the patient would not be able to see where he is walking; nor would he be able to eat in a normal way: therefore fixation of the epistropheus must be regarded as ineffective. It is, however, possible that such a plaster bandage would facilitate muscular immobilisation of the epistropheus and thereby favour healing.

SULLIVAN considered a reposition under anesthesia as too risky in inexperienced hands and therefore suggested reposition by traction. Under anesthesia there is, it is true, a risk of dislocation resuming its primary forward type with the neurologic consequences such dislocation might involve. In the first part of this investigation the membrana tectoria has been shown to inhibit longitudinal translation (p. 60). Therefore, it is this ligament that is influenced by longitudinal traction. In relation to the longitudinal axis this ligament is oblique with its dorsocaudal origin on the epistropheus and cranioventral attachment on the cranium. On longitudinal traction the ligament will tend to assume a longitudinal course whereby the dislocation forwards of the cranium can be reduced. The position of the cranium during longitudinal traction is probably irrelevant. The effect of reposition can, however, probably be increased by applying traction somewhat dorsally. In the position suggested by SULLIVAN with dorsal flexion of the head there is a risk of traction being somewhat in ventral direction and thereby fail to reduce the dislocation. It therefore appears better to perform traction with a slight forward bend of the cervical spine such as may be produced by placing a round pad under the back of the neck whereby it is possible to secure somewhat dorsally directed traction.

Three of the 7 cases of spontaneous atlas dislocation described had occurred two or several years earlier during the course of polyarthritis and may therefore be regarded as inveterate (cases 2, 3, and 4). One (No. 3) of these cases received traction treatment for 2 months without any demonstrable effect. Three of the remaining 4 (Nos. 1, 5, and 7) received traction treatment and were then immobilised in craniothoracic plaster, while one without demonstrable forward dislocation (No. 6) was treated with a craniothoracic bandage. Apart from partial persistent dislocations the functional results were good in all. In 1 case (No. 5) the dislocation was no longer demonstrable clinically or roentgenologically after 8 days' traction but it recurred during subsequent immobilisation in plaster. In case No. 6 treatment with a bandage in order to immobilise the cranium in torticollis position was a necessary makeshift.

Since no dislocation forward was demonstrable recovery might be expected. Although immobilisation was not satisfactory the result obtained was equally good as that achieved in treatment of case No. 5 in which no dislocation forwards was demonstrable either and which after a short period of traction was reduced with disappearance of the symptoms after which the patient was treated with plaster. In both cases symptoms disappeared without any subsequent limitation of mobility. Axial roentgenograms afterwards, however, suggest a certain persistent lateral displacement of atlas in both cases.

The material is non-informative as to the value of prolonged traction but in view of the good primary results achieved in cases 5 and 7 already after short traction and in view of the fact that traction appears to be the only way in which reduction can be maintained this procedure will be applied in future in order to offer the transverse ligament a possibility of healing in a reduced position.

GROGONO suggested surgical immobilisation of the atlas in relation to the epistropheus in recurrent atlas dislocation. None of the cases were operated on in the present material. It is possible that such an operation or a similar surgical procedure might be indicated in those cases of chronic joint diseases where ordinary treatment is followed by recurrences with serious clinical symptoms, as in the cases described by TITRUD et al. and MARGULIES et al. The subsequent limitation of turning of the head after such an operation, on the average 47°, must be borne in mind. But this might nevertheless be less inconvenient than the impossibility to turn the head in one direction such as in case 2.

PROGNOSIS OF DISLOCATION OF THE ATLAS

Fatal cases of spontaneous atlas dislocation are on record (BELL, WATSON-JONES, RAMOND, APERT et al.). Neurologic symptoms have usually caused the examiners to direct attention to the possibility of a compression of the medulla oblongata. The possibility of a sudden unexpected death because of compression of the medulla oblongata in dislocation of the atlas should be considered although no such case is on record.

The almost regular reversibility of neurologic symptoms suggests that this is due to partial or complete reduction of the forward dislocation on assumption of a torticollis position. The temporary neurologic symptoms may be regarded as a consequence of transient pressure against the medulla oblongata.

The end-results of the treated and untreated cases in the present material agree well with those described by HESS et al. and BLUNCK who in an examination of a few earlier diagnosed cases found persistant dislocation of the atlas forwards and what they called compensatory cervical scoliosis.

It is striking that all the present 3 inveterate cases were seen in patients with chronic polyarthritis which seems to suggest that the persistant dislocation is a consequence of arthritic processes. As far as the non-arthritic cases are concerned it must be assumed that the affection of the transverse ligament healed with the vertebrae in the position they have in torticollis. Normal articulation of the atlo-axoid joint might not be recovered, such as in cases with persistant dislocation forward. Since the functional results achieved in the treated cases with persistant dislocation were good, there is reason to suppose that the functional result of untreated cases might be so good as not to leave behind any striking symptoms.

SUMMARY

Literature studies on so-called spontaneous or non-traumatic atlas dislocation revealed vague and contradictory data which required investigation of the anatomy and function of certain details in the craniovertebral joints, which are accounted for in Part I of this work.

A search of the literature revealed 205 cases of atlas dislocation in the absence of known fracture of the atlas or the epistropheus. In the literature the distinction between traumatic and non-traumatic atlas dislocation is diffuse. In the present investigation it was therefore studied to what extent acceleration force, *i. e.* mainly horizontal force, can damage the craniovertebral ligaments without skeletal fracture. No such case was found. The ligaments were found to be of such strength that they could withstand a force greater than that capable of producing a cranial or a cervical vertebral fracture. Trauma in connection with atlas dislocation without fracture of the atlas or the epistropheus must therefore be regarded as being of secondary etiologic importance.

The investigation described in Part I showed that atlas dislocation is possible only on complete rupture of the transverse ligament. Thus, partial rupture will not lead to atlas dislocation. If the transverse ligament is ruptured, the extent of the dislocation is determined by the length of the alar ligaments, since these ligaments are slack in midpositions.

It thus appears that the conception of the underlying mechanism and clinical types of atlas dislocation must be revised. The development of atlas dislocation is probably uniform, a primary dislocation forwards, with a secondary torticollis. For the final position of dislocation two main alternatives are available, with reduced or unreduced primary dislocation forwards.

In the first alternative the dislocation position in some cases may hardly be distinguished from normal position of rotation in the atlo-axoid joints. In the other cases as in the latter alternative, the spinal process of the epistropheus is displaced laterally in relation to the external occipital protuberance. In the latter alternative there is also a demonstrable pathologic diastasis in the anterior odontoid joint.

Within a period of three years a deliberate search revealed 7 cases of atlas dislocation among the clientele of the University Hospital, Lund.

In the treatment of 3 cases craniothoracic plaster fixation failed to produce the desired effect. The investigation carried out in Part I also showed that fixation of the atlo-axoid joints in insufficiency of the transverse ligament cannot be expected from such fixation.

In the treatment of atlas dislocations it should be borne in mind that reposition can only be maintained in longitudinal extension, by he function of the membrana tectoria.

Despite the fact that the dislocation was not completely reduced, four of the patients showed a good range of motion, which suggests that good functional results can be expected even in untreated cases.

Three inveterate cases with persistent torticollis and impaired range of movement were, however, seen in patients with polyarthritis, which suggests that the persistence of these symptoms was due to arthritic processes.

ACKNOWLEDGEMENTS

I wish to express my sincere thanks above all to Professor Gunnar Wiberg and Professor Carl-Herman Hjortsjö for generous help and advice throughout the investigations.

Acknowledgement is due to:

Docent Olof Norman for generous help with roentgenexaminations; Professor Folke Linell and Docent Hjalmar Sjövall for placing material to my disposal and Docent Bertil Nilsson for generous advice on physical questions.

BIBLIOGRAPHY

APERT, ODINET & LANG: Syndrome bulbaire progressif mortel consécutif a une luxation de l'atlas. Presse méd. p. 72, 1928.

BAKKE, S. N.: Röntgenologische Beobachtungen über die Bewegungen der Wirbelsäule. Acta radiol. Suppl. 13, 1931.

BARATOUX, J.: Un cas de maladie de Grisel. Presse méd. p. 1714, 1931.

BELL, CH.: Physiologische und pathologische Untersuchungen des Nervensystems. Berlin 1836. Translated by Dr. med. M. H. Romberg. Original title: The Nervous System of the Human Body. London 1830.

BERKHEISER, E. J. & SEIDLER, F.: Nontraumatic Dislocations of the Atlanto-Axial Joint. J. A. M. A. 96: 517—523, 1931.

BLAINE, E. S.: Manipulative (Chiropractic) Dislocations of Atlas. J. A. M. A. 85: 1356—1359, 1925.

BLASIUS, E.: Die traumatische Wirbelverrenkungen. Vrtljschr. f. d. prakt. Heilk. (Prag), bd 102—104, 1869.

BLOUNT, W. P.: Fractures in Children. Williams & Wilkins Co. Baltimore 1954.

BLUNCK, C.: Über die Atlasluxation. Beitr. klin. Chir. 162: 189—295, 1935.

BOEVER, F. & HENNEBERT, P.: Les dislocations non traumatiques de la colonne cervicale. Rev. chir. orthop. 39: 24—69, 1953.

BÖGER: Ein Fall von Malum suboccipitale rheumaticum. Arch. ortop. u. Unfall-Chir. 3: 97—100, 1905.

BRAV, E. A.: Voluntary Dislocation of Neck. Am. J. Surg. 32: 144—149, 1936.

BRINKMANN, E.: Die Drehungsverrenkung des Atlas. Klin. Wchnschr. 7: 649 —650, 1928.

BROCHER, J. E. W.: Die Occipito-Cervical Gegend. Thieme, Stuttgart 1955.

BROMAN, I. & HJORTSJÖ, C.-H.: Människans rörelseapparat. Gleerup, Lund 1952.

BROOKES, TH. P.: Dislocations of the Cervical Spine. J. A. M. A. 104: p. 902, 1935.

BROOKES, TH. P. & EWERHARDT, F. H.: On Reducing and Treating Cervical Dislocations. Arch. phys. Therap. 13: 463—467, 1932.

BOURGEOIS, H. & GRISEL, P.: Un nouveau cas de torticolis naso-pharyngien. Presse méd. p. 722, 1931.

CHARBONNEL, FARGES & LAFITE-DUPONT: Arthrites cervicales et torticolis naso-pharyngien. Presse méd. p. 681, 1931

CORNER, E. M.: Rotary Dislocations of the Atlas. Ann. Surg. 45: 9—26, 1907.

COUTTS, M. B.: Atlanto-Epistropheal Subluxations. Arch. Surg. 29: 297—311, 1934.

DALLY: Du torticolis occipito-atloidien. Bull. gen. de thérap. etc., Paris, pp. 354—356, 388—400, 1875.

DANKMEIJER, J. & RETHMEIER, B. J.: The Lateral Movement in the Atlanto-Axial Joints and its Clinical Significance. Acta radiol. 24: 55—66, 1943.

DELGOFFE, A.: La soit-disant énucléation de l'atlas et le torticolis. Rev. d'orthop. 21: 5—12, 1934.

DESFOSSES, P.: Un cas de maladie de Grisel. Presse méd. pp. 1179—1180, 1930.

DUMÉRIL: (discuss.): Gaz. méd. de France, p. 653, 1840.

EHRLICH, J. A.: Chirurgische Beobachtungen, pp. 199—213. Leipzig 1795.

ELY, L. W.: Subluxation of the Atlas. Ann. Surg. 54: 20—29, 1911.

ENGLANDER, O.: Non-Traumatic Occipito-Atlanto-Axial Dislocation. Brit. J. Radiol. 15: 341—345, 1942.

EXNER, G.: Die Halswirbelsäule. Thieme, Stuttgart 1954.

FELIX, W. & LÜDECKE, E.: Die lymfogene Schiefhals. Ztschr. f. orthop. Chir. 50: 329—337, 1929.

FICK, R.: Handbuch der Anatomie und Mechanik der Gelenke. Jena 1904—1911.

— Übersicht über die Fragen der Gelenk- und Muskelmechanik. Zschr. f. orthop. Chir. 51: 320—337, 1929.

FITZWILLIAMS, D. C. L.: Inflammatory Dislocation of the Atlas. Brit. Med. J. 2: 107—109, 1934.

GARNIER, M. P. & DELON, S.: Quadriplégie par rhumatisme cervicale. Guérison. Bull. soc. de pédiat. de Paris, pp. 139—141, 1930.

GERLACH, L.: Ueber die Herstellung anatomischer Präparate nach der van Vetter'schen Glycerinmethode. Sitzungsb. d. phys. med. Soc. zu Erlangen, 11. Heft: 205—210, 1879.

— Ueber die Bewegungen in den Atlasgelenken und deren Beziehungen zu der Blutströmung in den Vertebralarterien. Gerlachs Beitr. zur Morphologie und Morphogenie I: 104—117, 1884.

GREELEY, P. M.: Bilateral (Ninety Degrees) Rotatory Dislocation of Atlas upon the Axis. J. Bone & Joint Surg. 12: 958—962, 1930.

GREIG, D. M.: Clinical Observations on the Surgical Pathology of Bone. Oliver and Boyd, Edinburgh and London 1931.

GRISEL, P.: Énucléation de l'atlas et torticolis naso-pharyngien. Presse méd. pp. 50—53, 1930.

GRISEL, P. & BOURGEOIS, H.: (ref.): Un nouveau cas de torticolis naso-pharyngien. Ann. oto-laryng. pp. 725—732, 1931.

GROGONO, B. J. S.: Injuries of the Atlas and Axis. J. Bone & Joint Surg. 36 B: 397—410, 1954.

GRUBER, W.: Ueber den gesammten Apparat der Bänder zwischen dem

Hinterhauptbeine und den obersten Halswirbeln überhaupt und einen neuentdeckten Appendix superior des Ligamentum cruciatum insbesondere. Müllers Arch. f. Anat., Phys. u. wissenschaftl. Med. pp. 291—315, 1851.

HECKER, P.: Appareil ligamenteux occipito-atloido-axoidien. Étude d'anatomie comparée. Arch. d'anat., d'hist. et d'embryol. 1923.

HEIKKILÄ, V.: Parotitis epidemican jälkeinen niveltulehdus atlaksen ja epistropheuksen välisessä nivelessä. Duodecim 53: 475—481, 1937.

HENKE, W.: Die Bewegung zwischen Atlas und Epistropheus. Ztschr. f. rat. Med. III. Reihe, Bd 2. Leipzig und Heidelberg 1858.

— Die Bewegung des Kopfes in den Gelenken der Halswirbelsäule. Zschr. f. rat. Med. III. Reihe, Bd 7. Leipzig und Heidelberg 1859.

— Handbuch der Anatomie und Mechanik der Gelenke. Leipzig und Heidelberg 1863.

HENLE, J.: Handbuch der systematischen Anatomie des Menschen, Bd I: 2. Braunschweig 1855—1856.

— Handbuch der systematischen Anatomie des Menschen, Bd I: 2. Braunschweig 1872.

HESS, J. H., BRONSTEIN, I. P. & ABELSON, S. M.: Atlanto-Axial Dislocations Unassociated with Trauma and Secondary to Inflammatory Foci in the Neck. Am. J. Dis. Child. 49: 1137—1147, 1935.

HJORTSJÖ, C.-H.: cit. Broman-Hjortsjö.

— Studier över käkledsmekaniken. Gleerup, Lund 1954.

— Studies on the Mechanics of the Tempomandibular Joint. Kungl. Fysiografiska Sällskapets Handlingar N. F. Bd 66, nr 2, 1955. Lunds Universitets Årsskrift N. F. Avd. 2, Bd 51, nr 2, 1955.

HOMMA, H.: Mechanik der Atlasverletzungen beim Sturz auf den Kopf. Arch. klin. Chir. 160: 151—164, 1930.

HUDSON, O. C.: Fractures and Dislocations of the Cervical Spine. J. Bone & Joint Surg. 17: 324—331, 1935.

HULTKRANTZ, J. W.: Zur Mechanik der Kopfbewegungen beim Menschen. Kungl. Sv. Vet. Akad. Handl. Bd 49, nr 8, Stockholm 1912.

JACKSON, H.: The Diagnosis of Minimal Atlanto-Axial Subluxation. Brit. J. Radiol. 23: 672—674, 1950.

JACOBS, CH. M.: Atlas and Axis Luxation. Am. J. Orth. Surg. 16: 357—364, 1918.

JACOBSON, G. & ADLER, D.: On Evaluation of Lateral Atlanto-Axial Displacement in Injuries of the Cervical Spine. Radiology 61: 355—362, 1953.

JOSTES, F. A.: Neck Pain. J. A. M. A. 118: 358—359, 1942.

KALENSCHER, I.: Ueber den sogenannten dritten Gelenkhöcker und die accessorischen Höcker des Hinterhauptbeins. Königsberg 1893.

KÖNIGWEISER, A.: Ueber die Beugungsluxationen des Atlas durch Muskelzug und deren Mechanismus. Ztschr. f. orthop. Chir. 49: 207—217, 1928.

KORNBLUM, D., CLAYTON, L. & NASH, H. H.: Nontraumatic Cervical Dislocations in Rheumatoid Spondylitis. J. A. M. A. 149: 431—435, 1952.

KOTSCHER, E.: Spontane Subluxation im Atlantoaxialgelenk bei entzündlichen Processen am Halse. Radiol. Clin. 24: 17—24, 1955.

LEGG, C.: Case of Rotatory Dislocation between the Atlas and Axis. Lancet II: p. 1382, 1893.

LERICHE, R. & POLICARD, A.: Les problèmes de la physiologie normale et pathologique de l'os. Masson et Cie, Paris 1926.

LOB, A.: Ueber einen Fall von spondylitischem Schiefhals nach isolierter Osteomyelitis des Epistropheus. Ztschr. f. orthop. Chir. 52: 109—113, 1930.

— Die Wirbelsäulenverletzungen und ihre Ausheilung, p. 186. Theime, Stuttgart 1954.

LOUNAVAARA, K. I.: Forward Subluxation of the Atlas Following Birth Trauma. Acta paediat. 37: 340—348, 1949.

LYSHOLM, E.: Apparatus and Technique for Roentgen Examination of the Skull. Acta radiol. Suppl. 12, 1931.

MALGAIGNE, J. F.: Traité des fractures et des luxations. Tome II. Paris 1855.

MARGULIES, M. E., KATZ, I. & ROSENBERG, M.: Spontaneous Dislocation of the Atlanto-Axial Joint in Rheumatoid Spondylitis. Recovery from Quadriplegia Following Surgical Decompression. Neurology 5: 290—294, 1955.

MATZDORF, H.: Röntgenuntersuchungen über die Bedeutung der Atlasregion als Krankheitsfaktor. Ztschr. f. Orth. 87: 165—174, 1956.

MERKEL, F.: Handbuch der topograph. Anat. II: 173—179, Braunschweig 1899.

MIXTER, S. J. & OSGOOD, R. B.: Traumatic Lesions of the Atlas and Axis. Ann. Surg. 51: 193—207, 1910.

MORRIS, H.: The Anatomy of the Joints of Man. London 1879.

NIEVERGELT, K.: Maladie de Grisel. Helv. Paed. Acta 6: 445, 1947.

ODELBERG-JOHNSON, G.: A Case of Cervical Spondylarthritis after Tonsillectomy. Acta orthop. scand. 2: 302—317, 1932.

OGILVY, CH.: Subluxations of the Atlas upon the Axis. Am. J. Orth. Surg. 12: 314—331, 1915.

ORFILA: Mémoir sur la suspension. Gazettes méd. Paris, pp. 652—653, 1840.

POIRIER, P.: Traité d'Anatomie humaine 1: 745—758, Paris 1893.

POIRIER, P. & CHARPY, A.: Traité d'Anatomie humaine 1: 74—89, Paris 1926.

RAMOND, L.: Une énigme. Presse méd. pp. 11—12, 1931.

— Le mot de l'énigme. Presse méd. pp. 155—156, 1931.

RANKIN, J. O.: Rotary Dislocation of Atlas on Axis. Am. J. Surg. 32: 27—36, 1936.

RATHKE, H.: Entwickelungsgeschichte der Natter. Königsberg, 1839.

RAUBER & KOPSCH: Lehrbuch und Atlas der Anatomie des Menschen, Abt. 2. Thieme, Leipzig 1922.

REDARD, P.: Le torticolis et son traitement. Carré et Naud, Paris 1898.

ROBERTS, S. M.: Fractures and Dislocations of the Cervical Spine. J. Bone & Joint Surg. 29: 477—495, 1937.

SAPPEY, PH. C.: Traité d'anatomie descriptive. Paris 1853.

SCHREIBER, G.: (discuss.) Soc. de pédiatrie de Paris, 28: 261—262, 1930.

SHARP, J. & PURSER, D. W.: (ref.): Subluxation of the Neck in Anchylosing Spondylitis. Lancet: 27—28, 1957.

SJÖVALL, HJ.: Om frakturer på halskotpelaren. Nord. Med. 20: 1777, 1943.

SPALTEHOLZ, W.: Handatlas und Anatomie des Menschen. Leipzig 1929.

STAMMERS, F. A. R.: Spontaneous Dislocation of the Atlas with Report of a Case. Lancet II: 1203—1205, 1933.

SUDECK, P.: Ueber die Drehungsverrenkungen des Atlas. Deutsche Ztschr. f. Chir. 183: 289—303, 1923.

SULLIVAN, A. W.: Subluxation of the Atlanto-Axial Joint: Sequel to Inflammatory Processes of the Neck. J. Pediat. 35: 451—464, 1949.

SWANBERG, H.: Anterior Dislocation of the Atlas Following Tonsillectomy. J. A. M. A. 72: 107—108, 1919.

— (discuss.) J. A. M. A. 96: 523, 1931.

TEDESCO, B., GRISEL, DESFOSSES & TASSIN: Deux nouveaux cas d'énucléation de l'atlas par torticolis naso-pharyngien. Bull. Soc. de pédiat. de Paris 18: 252—262, 1930.

TITRUD, L. A., MCKINLAY, C. A., CAMP, N. E. & HANNAH, H. B.: Non-Traumatic Atlanto-Axial Dislocation. Report of a Case with Recovery after Quadriplegia. J. Neurosurg. 6: 174—180, 1949.

WAGNER, W. & STOLPER, P.: Die Verletzungen der Wirbelsäule. Deutsche Chir., Lieferung 40: 284—302, Stuttgart 1898.

WALTON, G. L.: A New Method of Reducing Dislocation of Cervical Vertebrae. J. Nerv. & Ment. Dis. 20: 609—611, 1893.

— Reduction of Cervical Dislocation: a Successful Case. Boston Med. & Surg. J. 129: 553—557, 1893.

— Further Observations on Cervical Dislocation and its Reduction. Boston Med. & Surg. J. 149: 445—447, 1903.

WATSON-JONES, R.: Spontaneous Hyperaemic Dislocation of the Atlas. Proc. Roy. Soc. Med. 25: 586—590, 1932.

WATSON-JONES, R. & ROBERTS, R. E.: Calcification, Decalcification and Ossification. Brit. J. Surg. 21: 461—499, 1934.

WATSON-JONES, R.: Fractures and Joint Injuries. Livingstone; Edinburgh 1943.

— Fractures and Joint Injuries, pp. 981—983. Livingstone; Edinburgh and London 1955.

WEBER, E. H.: Anatomisch-physiologische Untersuchung über einige Einrichtungen im Mechanismus der menschlichen Wirbelsäule. Meckels Arch. f. Anat. u. Phys. p. 243. Leipzig 1827.

— Messungen der Grösse der Bewegungen, dessen die Wirbelsäule und einige andere Gelenke fähig sind. Meckels Arch. f. Anat. u. Phys. pp. 261—267, 1827.

WEBER, W. & WEBER, E.: Mechanik der menschlichen Gehwerkzeuge. Wilhelm Webers Werke. Bd 6. Springer, Berlin 1836.

WERNE, S.: Spontaneous Atlas Dislocation. Acta Orth. Scand. 25: pp. 32—43, 1955.

WILSON, M. J., MICHELE, A. A. & JACOBSON, E. W.: Spontaneous Dislocation of the Atlanto-Axial Articulation, Including a Report of a Case with Quadriplegia. J. Bone & Joint Surg. 22: 698—707, 1940.

VIRCHOV, H.: Die sagittalflektorische Bewegung der menschlichen Halswirbelsäule. Arch. f. orthop. u. Unfall-Chir. 26: 1—42, 1928.

WITTEK, A.: Ein Fall von Distensionsluxation im Atlanto-epistropheal-Gelenk. Münchner Med. Wchnschr. 35: 1836—1837, 1908.

WOOD-JONES, F.: The Ideal Lesion Produced by Judical Hanging. Lancet I: p. 53, 1913.