J. Anat. (1977), **124**, 3, pp. 541–553
With 34 *figures*
Printed in Great Britain

Surgical aspects of the anatomy of the sphenoidal sinuses and the sella turcica

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(*Accepted* 10 *December* 1975)

INTRODUCTION

The sphenoid sinuses both literally and metaphorically occupy a central place in skull base surgery, for the trans-sphenoidal route is common to all operative approaches to the pituitary gland through the nose.

Pre-operative roentgenological evaluation of the sphenoid sinuses and the sella turcica, in addition to the usual lateral and anterio-posterior exposures, should include axial (submento-vertical) pictures and serial tomograms, paying special attention to pneumatization, irregularities, the position of the intersinus septum and the presence of extrasepta. Pneumoencephalography is usual, but internal carotid angiography is reserved for cases with suspicious parasellar growths.

The following account of the anatomy of the sphenoidal sinuses and the sellar turcica is based on the study of autopsy and surgical material, including a clinical analysis of 80 acromegalic patients.

THE SPHENOID SINUSES

Pneumatization

The sphenoid sinuses form irregular cavities inside the body of the sphenoid (Figs. 1, 2). They are contiguous with the posterior ethmoidal cells, and are closed anteriorly by the conchae sphenoidales. Development of the sphenoidal sinuses starts during the first year after birth with the formation of small recesses from the sphenoidal conchae on each side. Full development is not achieved until the end of the growth period.

With regard to the trans-sphenoidal surgical approach to the pituitary the sphenoidal sinuses may be divided into three groups (Hammer & Rådberg, 1961):

(1) The *conchal* type, with a very small sinus which is separated from the sella turcica by a wall of cancellous bone approximately 10 mm thick;

(2) the *presellar* type, in which the sinus does not extend posterior to a line running perpendicular to the sphenoidal plane through the tuberculum sellae;

(3) the *sellar* type, in which the sinus extends behind the aforementioned line, and the floor of the sella appears as a protrusion into the sphenoidal sinuses.

In a series of 80 patients with acromegaly treated by trans-sphenoidal surgery of the pituitary adenoma, I found that the pneumatization of the sphenoid sinuses was of the sellar type in 88·8 %, including one case with the sellar type of pneumatization on one side and a non-pneumatized, conchal sinus on the other side (Figs. 7, 8). Presellar pneumatization was seen in the remaining 11·2 %, including one case with presellar type of pneumatization on one side and conchal type on the other (Table 1).

Table 1. *Roentgenological findings regarding the sphenoid sinuses in 80 acromegalic patients*

Pneumatization	Conchal	2	(one right, other left side only)
	Presellar	9	(left side only, in one case)
	Sellar	71	(right side only, in one case)
Intersinus septum	Deviation to the right	27	
	In the midline	32	(absent or destroyed in four cases)
	Deviation to the left	17	
Extra septa	Sagittal–lateral	9	
	Medial	1	
	Frontal–lateral	5	
Asymmetry of sellar floor	Bulging on right side	18	
	Bulging on left side	18	

Intersinus septum. Extra septa

Onodi (1911) observed that the intersinus septum often deviated laterally in its posterior part. Hammer & Rådberg (1961) found that the intersinus septum ran in the midline throughout its course in approximately 25 % of cases. They also pointed to the surgical importance of extra septa in the sphenoidal sinuses – medial, frontal, lateral and sagittal–lateral.

In our series the intersinus septum was in 41·9 % of cases situated in the midline, in 35·5% there was a deviation to the right and in 22·4 % to the left – in four cases the septum could not be identified or had been partially destroyed (Figs. 9–12; Table 1). Extra septa, most commonly sagittal–lateral – i.e. incomplete or complete septa parallel and lateral to the intersinus septum – were seen in 15 sinuses (Figs. 4, 13–16; Table 1).

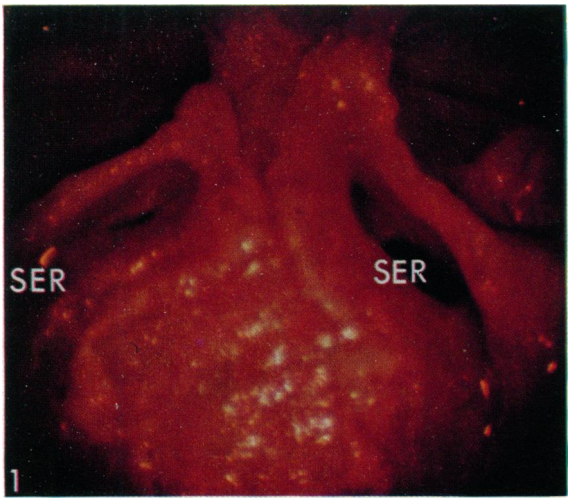
The entrance to each sphenoidal sinus was in the spheno-ethmoid recess above the superior concha, 7 cm from the anterior nasal spine (Fig. 2).

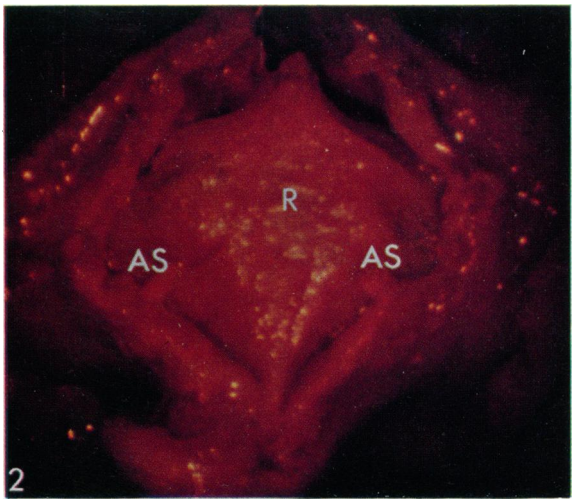
Surgical aspects

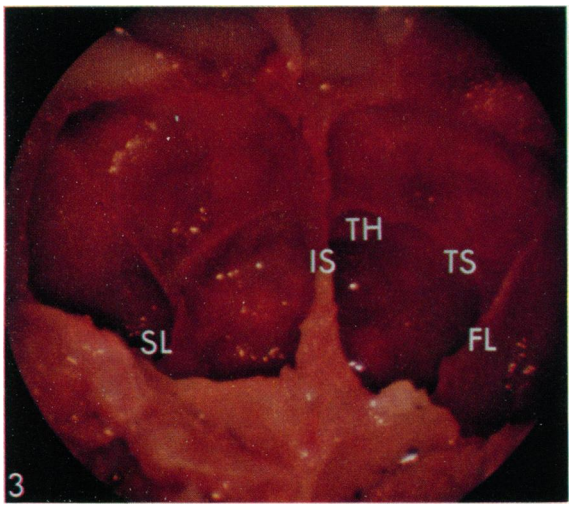
Certain anatomical facts have to be considered in trans-sphenoidal surgery:

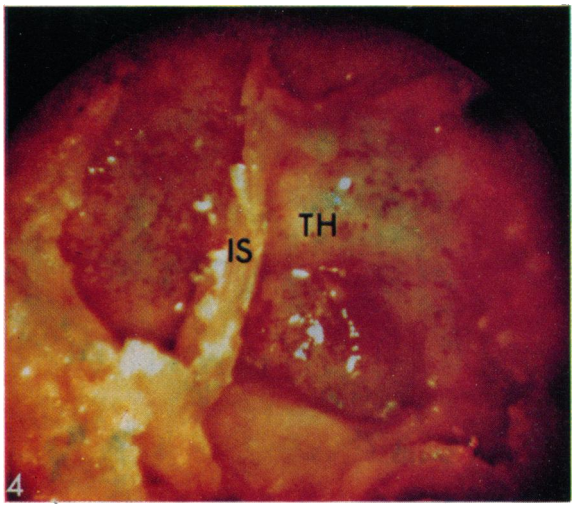
(1) Posterior ethmoidal cells may surround the sphenoidal body, and accordingly may contribute to the sella turcica or the trigonum presellare (Onodi, 1911; Hammer & Rådberg, 1961; Radojevic, Jovanovic & Lotric, 1969). The spheno-ethmoidal recess may reach the anterior wall of the sella, in which case the sella will take part in the delineation of the posterior wall of the nasal cavity (Pećina & Novoselac, 1970).

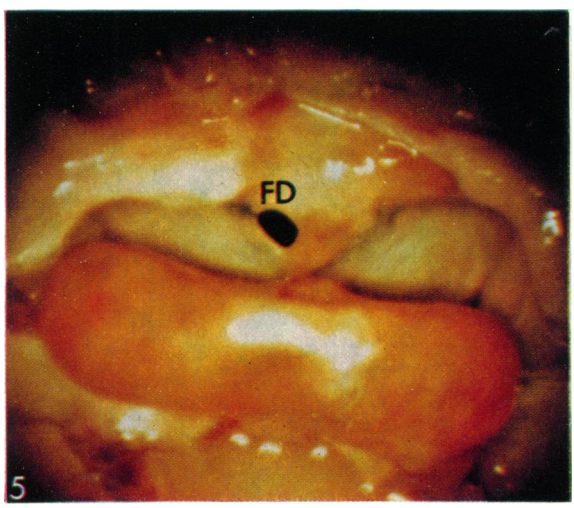
Fig. 1. In trans-sphenoidal surgery the spheno-ethmoidal recesses (SER) and the openings to the sphenoid sinuses are important landmarks.
Fig. 2. The sphenoid body with rostrum sphenoidale (R) and the arteria spheno-palatina (AS).
Fig. 3. The intersinus septum (IS) in this preparation is in the midline. A sagittal–lateral (SL), a frontal–lateral (FL) and a transverse (TS) septum can be identified. The torus hypophyseos (TH) is observed at the posterior attachment of the transverse septum.
Fig. 4. The intersinus septum (IS) often deviates more or less to one side, and the posterior attachment in such case is lateral to the anterior wall of the sella (TH).
Fig. 5. The pituitary gland is surrounded by a dural envelope, which, in this case, has been opened by a cruciate incision. The pituitary stalk has been sectioned and the foramen diaphragmatis (FD) is visible.
Fig. 6. The pituitary gland has been removed as well as the bony carotid wall in this preparation. The distance between the carotid siphons (AC) averages 14 mm. Foramen diaphragmatis, FD; dorsum sellae, DS.

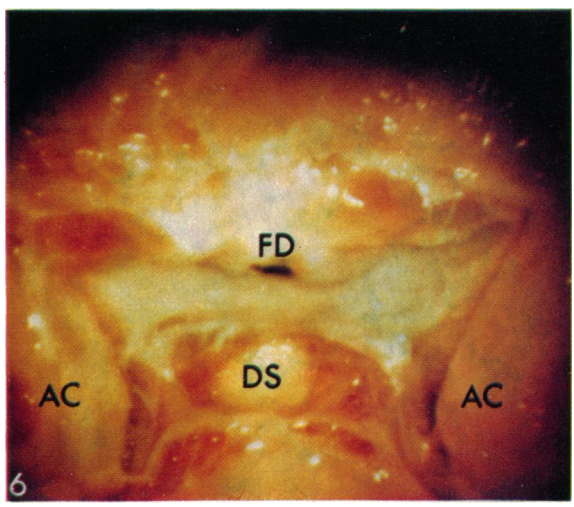












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(2) The posterior part of the instersinus septum often deviates to one side, and is accordingly attached laterally to the anterior wall of the sella, sometimes as far laterally as in the carotid prominence (Fig. 3). The sagittal–lateral septa often have their posterior attachment at the carotid prominence (Fig. 4).

(3) In some cases the bulging of the anterior wall of the sella, the torus hypophyseos, is unremarkable or totally lacking (Radojevic *et al.* 1969) (Figs. 3, 17, 18). This is, however, seldom the case in acromegaly.

(4) The distance between the carotid siphons (Fig. 6) averages 14 mm (Bergland, Ray & Torack, 1968), and the carotid arteries are usually not in contact with the pituitary, but as they become tortuous in older patients they may protrude into the sellar cavity. Occasionally, as a congenital variation, the carotid arteries are situated medial to the inner aspect of the cavernous wall rather than inside it (Hardy, 1969).

(5) Bridging connective tissue bands may extend from the carotids to the pituitary capsule. The intercavernous (circular) sinuses are usually described as small spaces within the substance of the diaphragma, but they may be large and, in many cases (85 %, Bergland *et al.* 1968), an anterior intercavernous sinus is present.

(6) The optic canal may have a part of its course, up to 10 mm, within the sphenoidal sinuses (Onodi, 1911).

THE SELLA TURCICA

Volume and shape

The sella must be studied in both frontal and lateral projections. A sella which, in the lateral view, is apparently large, may actually be narrow and, contrariwise, a small sella in the lateral view may be broad in the frontal view (Rådberg, 1963; Laurén, 1969).

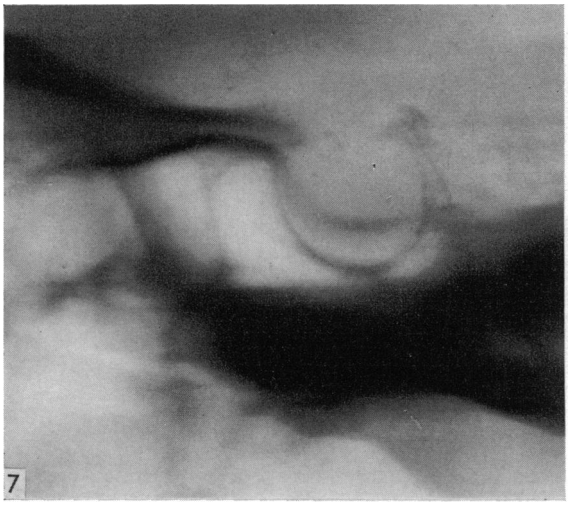
Much attention has been paid to the assessment of the volume of the sella turcica. The upper limit has been estimated to be 1092 mm^3 (di Chiro & Nelson, 1962) and 1960 mm^3 (Oon, 1963, in an Asian population). Ross & Greitz (1966), in material from 24 patients with 'eosinophilic' adenomas, found a mean volume of 4460 mm^3, the corresponding figures for 'chromophobic' adenomas being 4540 mm^3. The normal variations are wide, and assessment of the sellar volume is of limited diagnostic value in the individual case. The hypophysis itself occupies only 50 to 85 % of the pituitary fossa, and it is assumed that it can almost double in size, mostly at the expense of venous filling without altering the bony sella (di Chiro & Nelson, 1962).

It is usually claimed that the sella in acromegaly is balloon-shaped, while with non-functioning, 'chromophobic' adenomas a cup-shaped or open sella is considered typical (Tänzer, 1970). As shown by Ross & Greitz (1966), this classical description is only statistically valid, and allows for no definite conclusions in the individual case.

Normally the angle between the planum sphenoidale and the anterior wall of the sella is approximately 90°; as the sella increases in size this angle becomes acute (Figs. 19, 20, 22).

The sellar floor

In ordinary lateral views the sellar floor may show one, two or even three contours, because of moderate lateral inclination and asymmetric enlargement (Rådberg, 1963; Laurén, 1969) (Figs. 7–10, 23–26).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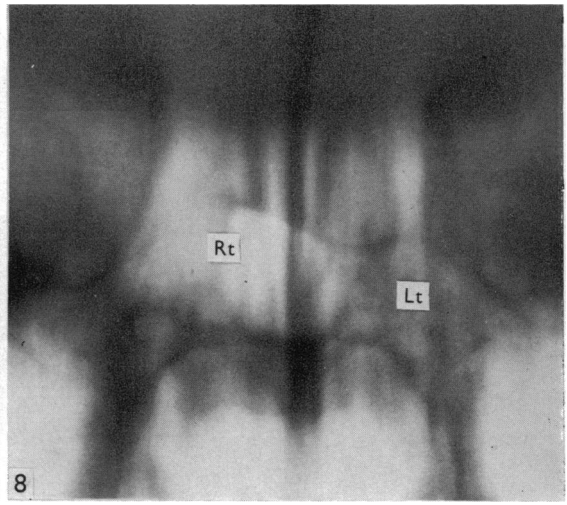

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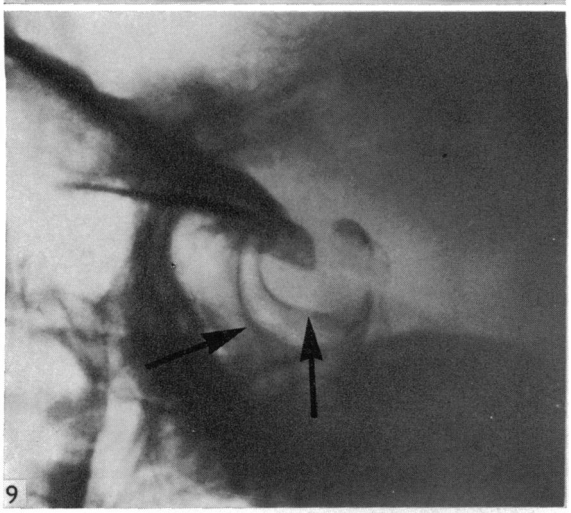
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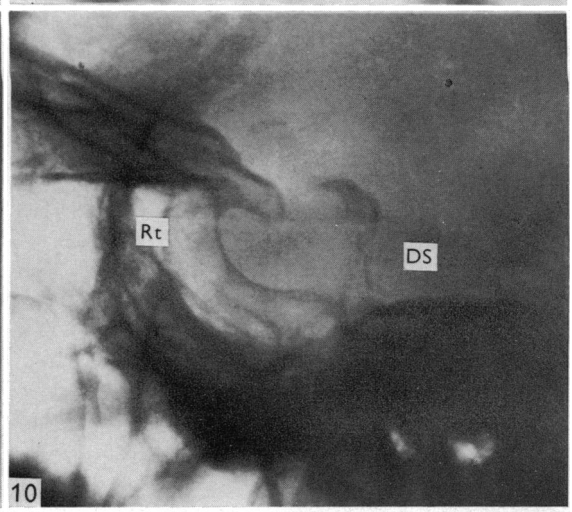

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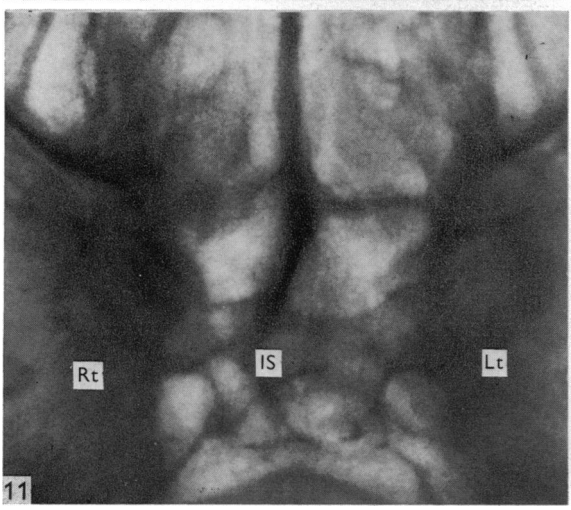

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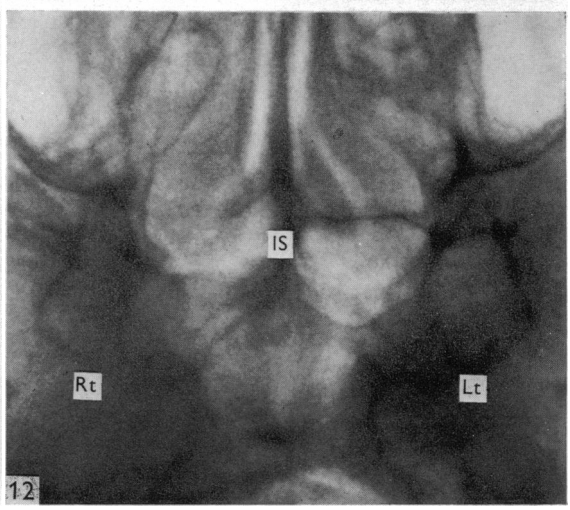

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In our series of acromegalic patients the sella turcica was enlarged, and of the balloon-type, in 93·7 % of the patients. Slight or no enlargement was seen in the remaining 6·3 %. In 36 cases there was conspicuous asymmetry of the sellar floor, with bulging down on the right or left (Table 1).

The dorsum sellae

Rarefaction and destruction of the dorsum sellae, reported to be more marked in 'chromophobic' adenomas, are also common in acromegaly (Lang & Bessler, 1961). In our series rarefaction of the dorsum sellae was seen in 23·8 % of the patients and destruction in 15 % (Figs. 7, 10, 20, 27, 29). A post-operative sellar reconstitution (decrease in size and re-calcification) was seen in 64·4 % of the patients. Regress within two to four months could be demonstrated in 36·2 % of the patients (Figs. 27–30, 31–34). The radiopaque structure seen post-operatively and corresponding to the site of the operation defect in the anterior wall of the sella, consists of a dense organic matrix and newly formed compact bone. Re-mineralization activity in the rebuilt area decreases gradually, reaching negligible proportions after a year (Hammer, Rådberg & Röckert, 1964). New bone formation may be very pronounced, and difficulties may be encountered at second operations (Heck, McNaught, Greenspan & Kaplan, 1957).

The pituitary envelope

It is important to know that with pituitary adenomas no capsule exists other than the pituitary envelope (Hardy, 1969, 1971). The pituitary envelope is in continuity with the lateral wall of the sella which forms the inner aspect of the cavernous sinus, and also with the diaphragma sellae (Figs. 5, 6). Any attempt to remove the 'capsule' will be followed by severe bleeding. Radical tumour excision can and should be accomplished without removal of the 'capsule'.

The diaphragma sellae

The trans-sphenoidal operative approach was designed on the assumption that the diaphragma sellae will serve as a barrier between the sella turcica and the intracranial space. The opening in the diaphragma sellae for the pituitary stalk, the foramen diaphragmatis (Hempel, 1970) (Fig. 5), is often greater than 5 mm wide and in 10 % of cases the diaphragma may be considered too thin to serve as a reliable barrier (Bergland *et al.* 1968). It has even been claimed that the diaphragma sellae

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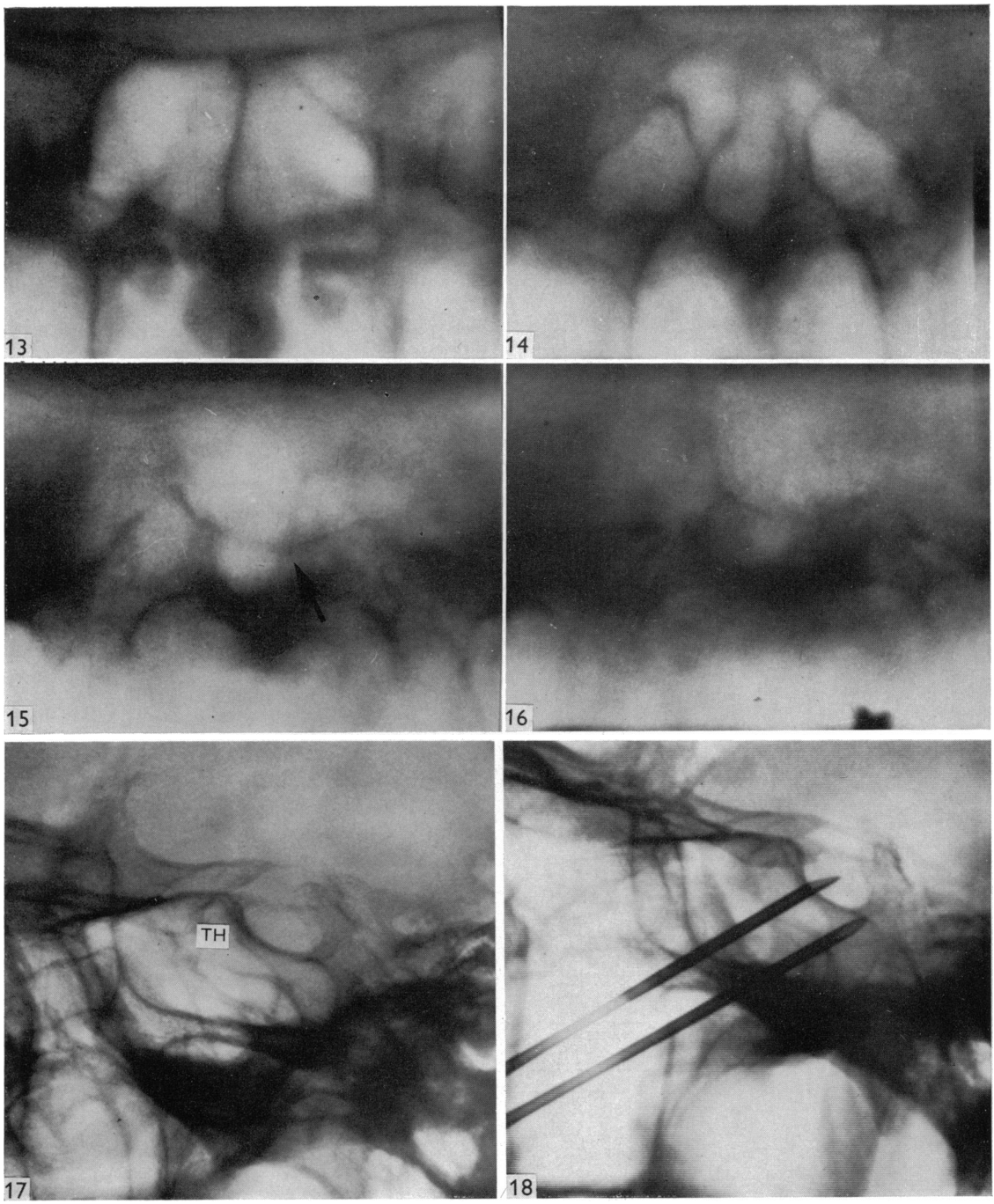
Figs. 7, 8. The pneumatization of the right sphenoid sinus is of the sellar type (Rt), while the left sphenoid sinus (Lt) is undeveloped, and the pneumatization on this side accordingly is of the conchal type. The sella is moderately enlarged, the floor appears with a double contour caused by the asymmetric enlargement, with bulging down mainly on the left side. An obvious rarefaction of the dorsum is observed. At operation the left sphenoid sinus was observed to consist of cancellous bone. On the right side the anterior wall of the sella was thin. Large tumour masses could be evacuated.

Figs. 9, 11. In 1961 roentgenograms showed an asymmetric sella which was not considered to be enlarged. The pneumatization of the sphenoid body is of the sellar type. In the side projection (Fig. 9) the sellar floor shows a double contour (→). The axial projection (Fig. 11) shows deviation of the intersinus septum (IS) to the right.

Figs. 10, 12. In April 1972 the roentgenograms showed a considrable enlargement of the sella, mainly on the right side (Rt). The dorsum sellae shows decalcification (DS). The posterior part of the intersinus septum (IS) has been destroyed by the tumour, which at operation was found to have broken through the anterior wall of the sella on the right side.



Figs. 13–16. Frontal tomography of the sella and the sphenoid sinus shows a moderate deviation of the intersinus septum to the left side. The sella is considerably enlarged, bulging down more on the left side (→). Frontal–lateral and sagittal–lateral septa are also observed. It was found at operation that the anterior wall of the sella was partially destroyed, but the pituitary capsule was intact.

Figs. 17, 18. Where the torus hypophyseos (TH) is less marked and the anterior wall of the sella is thick, the orientation may be difficult. If doubts should arise concerning the position of the sella, indicators may be applied against the assumed anterior border, and lateral and antero-posterior roentgenograms taken with a portable machine.

in 65 % of normal pituitary fossae consists only of arachnoid (Shealy, Jackson, Pearson & Kaufman, 1968).

It is usually assumed that the diaphragma extends from the superior aspect of the posterior clinoid process to the superior margin of the tuberculum sellae. The attachment is, however, often found several mm below this point (Bergland *et al.* 1968). This has to be remembered in classifying tumours as infra- or supra-diaphragmatic.

The pneumoencephalographic categories

Pituitary tumours may be divided, for practical surgical purposes, into four pneumoencephalographic categories (Stern & Batzdorf, 1970):

(1) no suprasellar mass,

(2) limited suprasellar mass; the extrasellar extension is smaller than the intrasellar mass,

(3) suprasellar mass greater than the intrasellar,

(4) third ventricle distortion irrespective of the relative sizes of the intra- and suprasellar masses).

To this should be added a fifth category:

(5) suprasellar mass with normal sella, a contra-indication for trans-sphenoidal surgery.

In our series suprasellar extension was proved to exist in 28·8 % of the patients, It is noteworthy that 60·8 % of the patients with suprasellar extension belonged to the fourth pneumoencephalographic category, with distortion of the third ventricle. (Figs. 20–21, 31–34).

Contraindications to trans-sphenoidal surgery

Contraindications to the trans-sphenoidal approach are:

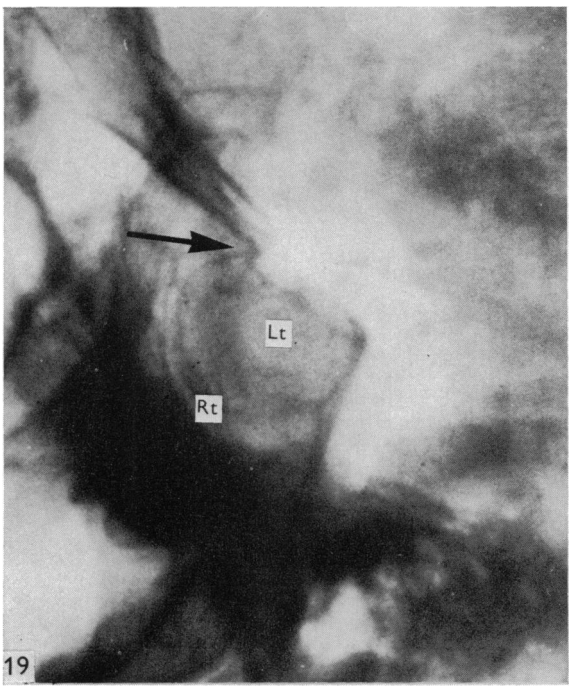
(1) A suprasellar mass with a normal sella turcica is an absolute contraindication to the trans-sphenoidal approach (Hardy, 1969).

(2) Hour-glass tumours (adénomes en sablier, Guiot, 1969) must be treated by the combined trans-sphenoidal and intracranial approach recommended by Burian (1971). This is especially the case with parasellar adenomas (Hardy, 1969) extending laterally, with widening of the carotid siphon or elevation of the carotid and proximal parts of middle cerebral arteries, erosion of the optic foramen and cavernous sinus, or trigeminal and oculomotor nerve symptoms (adénomes envahissants, Guiot, 1969).

(3) Nasal and paranasal sinus infections.

(4) Superior vena cava obstruction, which makes the control of cerebrospinal fluid escape difficult because of its raised pressure (Thomas, 1966),

(5) Conchal type of pneumatization of the sphenoid body. This is seldom encountered in acromegaly, but is considered a contraindication to the trans-sphenoidal approach. The difficulties, however, may nowadays be overcome by televised radiofluoroscopic control, as advised by Hardy (1971).



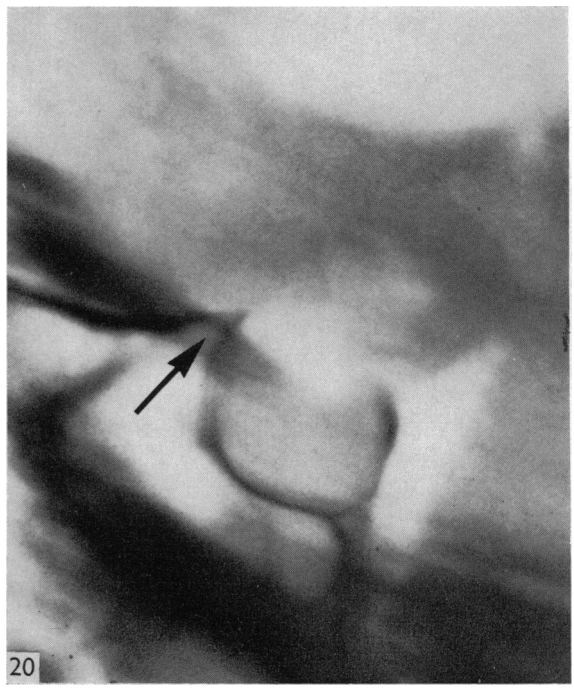
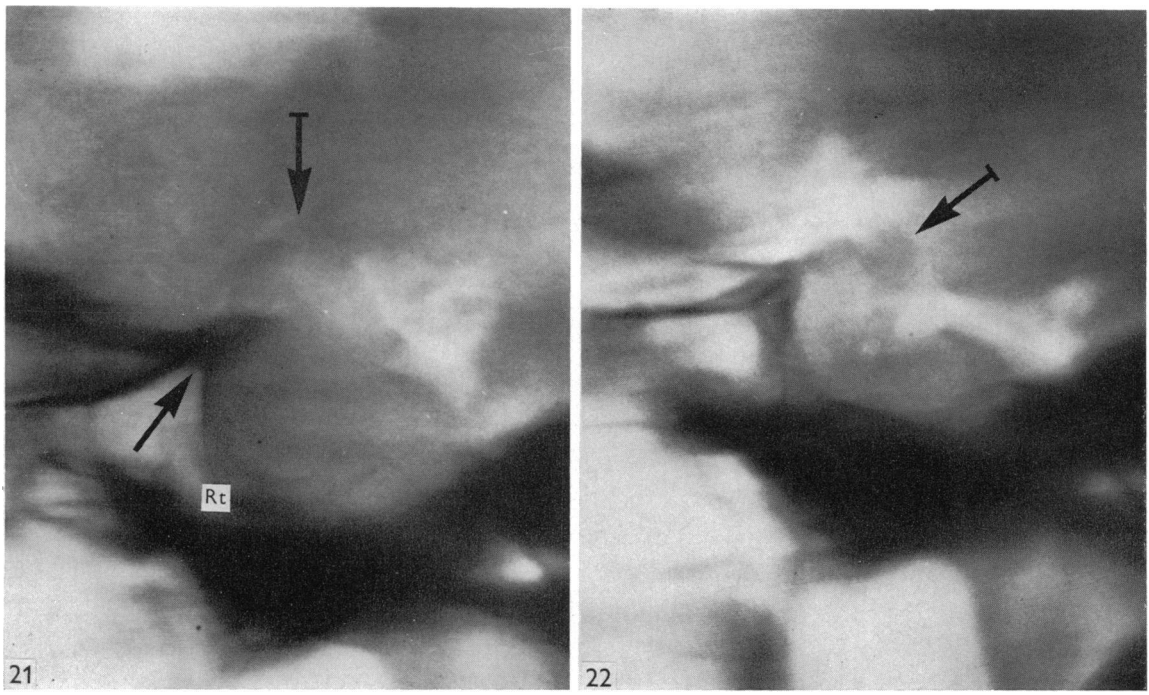
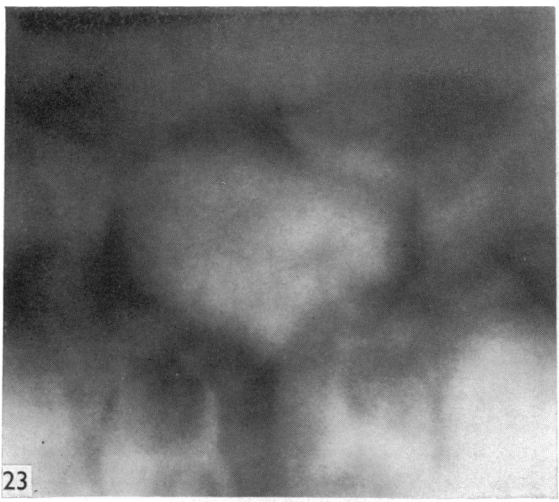


Fig. 19. The pneumoencephalogram shows a considerably enlarged, balloon-shaped sella. The angle between the planum sphenoidale and the anterior wall of the sella is acute (→); the floor appears with a double contour (right, Rt; left, Lt).

Fig. 20. Pneumoencephalogram shows a considerably enlarged sella. The angle between the planum sphenoidale and the anterior wall of the sella is acute (→), the pneumatization of the sphenoid body being of the sellar type.



Figs. 21, 22. The pneumoencephalogram February 1971 (Fig. 21) shows a considerably enlarged sella, bulging down more on the right (Rt) side. The angle between the planum sphenoidale and the anterior wall of the sella is acute (→). A considerable suprasellar extension is observed (↦). Pneumoencephalogram September 1972, 1½ years after operation, shows that the suprasellar (supradiaphragmatic?) portion of the tumour had prolapsed down into the sella (↦), which roentgenologically was considered 'empty' after the transphenoidal operation. The sella has decreased in size and re-calcification was observed.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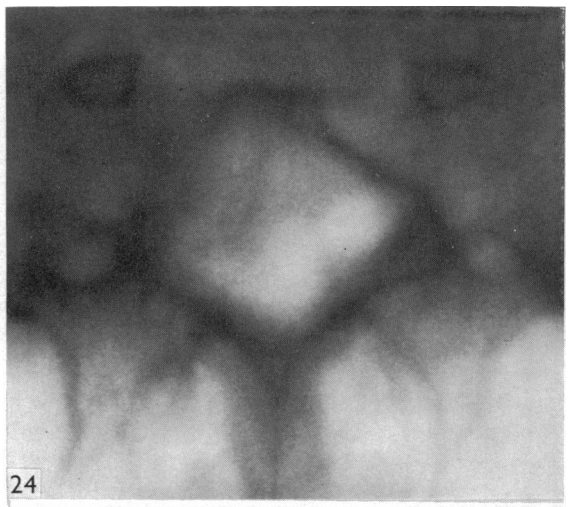
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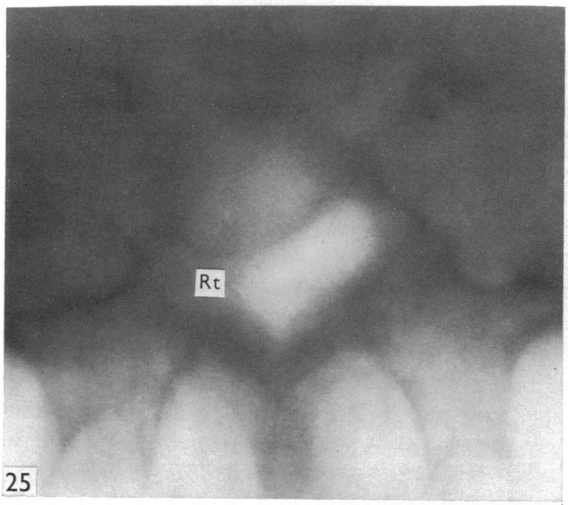

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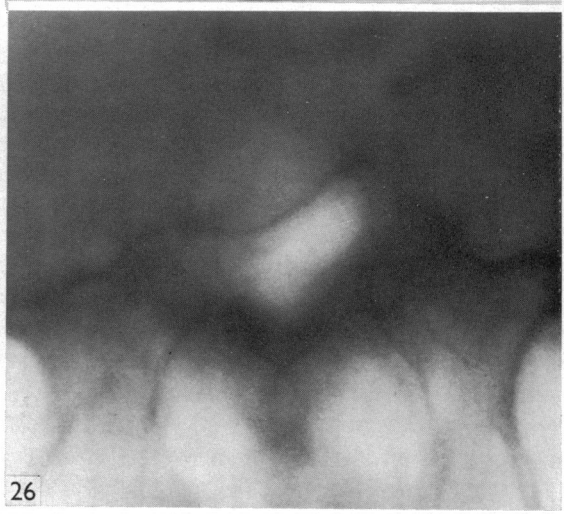
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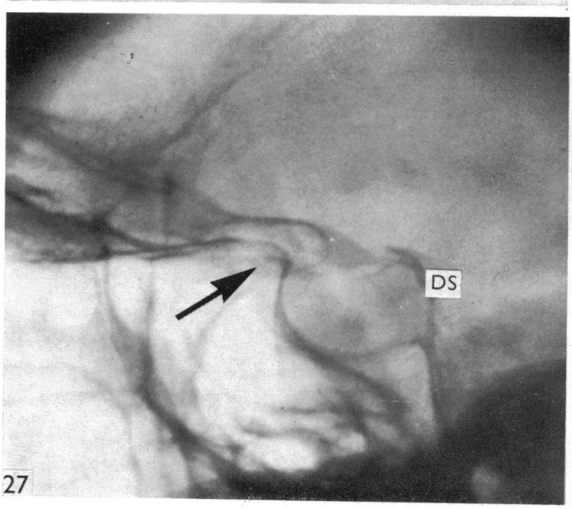

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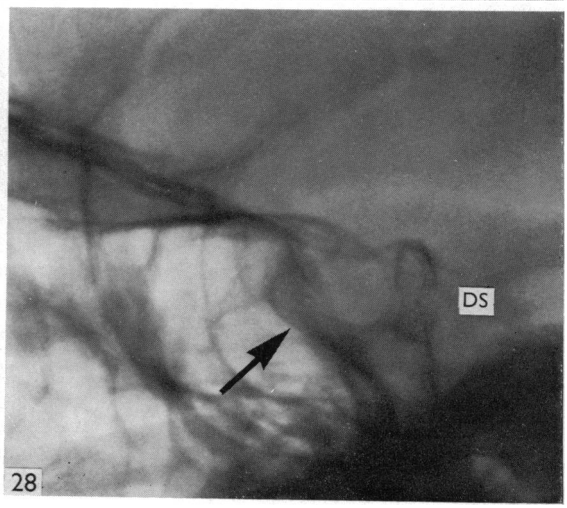

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SUMMARY

The anatomy of the sphenoidal sinuses and the sella turcica from surgical material and autopsy specimens has been studied. In 80 acromegalic patients pneumatization was of the sellar type in 89 %, while a conchal type of pneumatization was found in one patient only. In this series the intersinus septum was in the midline in only 42 % of cases. Extra septa were found in 15 sinuses. The intersinus septum, as well as the extra septa, may have their posterior attachment at the carotid prominence. Posterior ethmoidal cells may form a part of the sella turcica or of the trigonum presellare. The carotid arteries become tortuous in older patients and may protrude into the sellar cavity. The optic canal may have a part of its course within the sphenoid sinus. The pituitary gland may double in size without necessarily altering the bony sella. In the expanding sella the angle between the planum sphenoidale and the anterior wall of the sella becomes acute. The floor of the sella in ordinary lateral views may show several contours because of lateral inclination or asymmetric sellar enlargement. Conspicuous asymmetry of the sellar floor was seen in 36 cases. Rarefaction or destruction of the dorsum sellae is common in acromegaly and was seen in 39 % of the patients. Post-operative sellar reconstitution was noted in 64 % of cases. New bone formation may be very pronounced, and difficulties may be encountered at a second operation. The relation between the pituitary gland or a pituitary tumour to the diaphragma sellae is important; supradiaphragmatic tumours without sellar extension should not be treated by the trans-sphenoidal operation.

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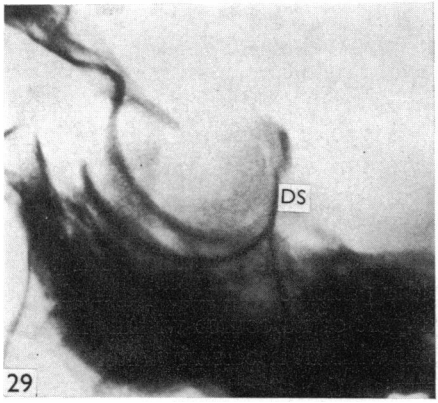
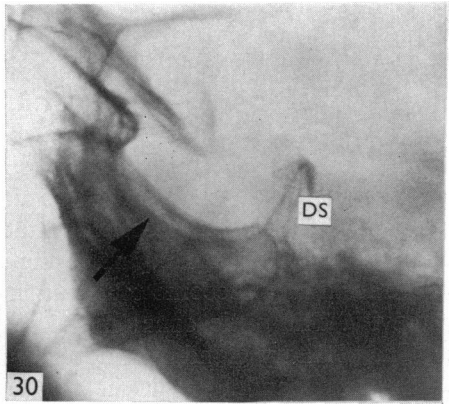
Figs. 23–26. Serial frontal tomograms show that the sellar floor is bulging down only on the right (Rt) side.

Figs. 27, 28. The roentgenogram December 1962 (Fig. 27) shows a balloon-shaped enlargement of the sella with rarefaction of the dorsum (DS). The angle between the planum sphenoidale and the anterior wall of the sella is around 90° (→). The pneumatization of the sphenoid body is of the sellar type. The last post-operative roentgenogram August 1967 (Fig. 28) shows a marked sellar reconstitution with re-calcification of the dorsum sellae (DS) and a considerable bony thickening of the anterior wall of the sella (→).



29



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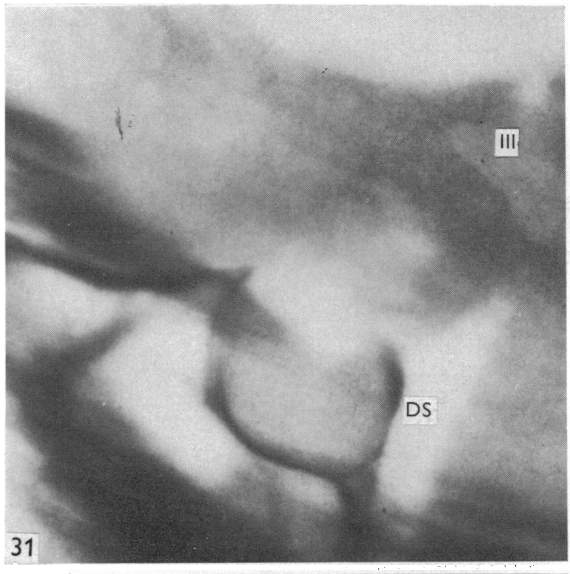
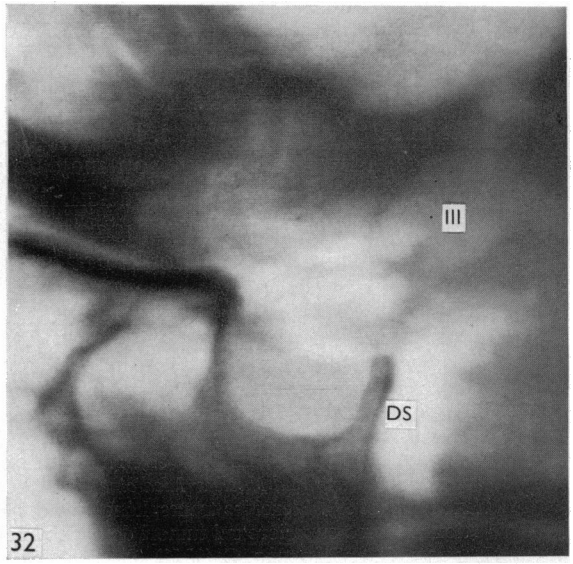
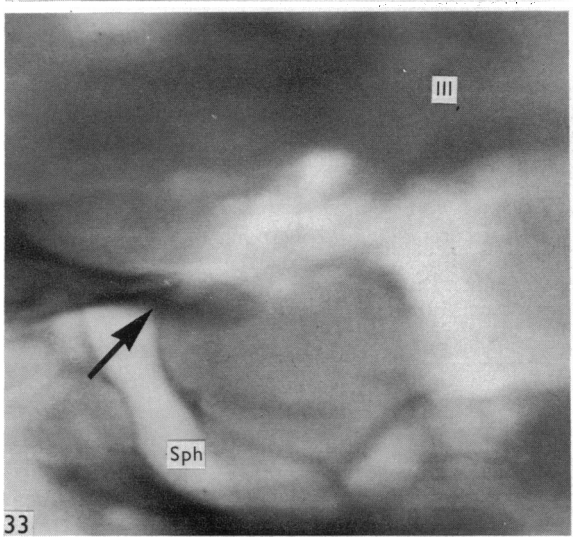


31



32



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Figs. 29, 30. The roentgenogram March 1967 (Fig. 29) shows a considerably enlarged asymmetric sella, leaving almost no cavity in the sphenoidal sinus. There is a rarefaction of the dorsum sellae (DS). The last post-operative roentgenogram December 1972 (Fig. 30) shows obvious sellar reconstitution with re-calcification of the dorsum sellae (DS) and considerable bony thickening of the anterior wall of the sella (→).

Figs. 31, 32. In this case there is a large suprasellar extension of the tumour with third ventricle distortion (III) (Fig. 31). At operation large tumour masses were evacuated. The post-operative pneumoencephalogram (Fig. 32), in addition to the sellar reconstitution with re-calcification of the dorsum sellae, shows disappearance of the suprasellar tumour with normalization of the suprasellar cisterns and the third ventricle (III).

Figs. 33, 34. Pneumoencephalogram June 1969 (Fig. 33) shows a considerably enlarged, balloon-shaped sella with rarefaction of the dorsum and considerable narrowing of the sphenoid sinus (Sph). The angle between the planum sphenoidale and the anterior wall of the sella is acute (→). There is a moderate suprasellar extension with a slight deformation of the anterior part of the third ventricle (III). The post-operative pneumoencephalogram December 1970, in addition to the sellar reconstitution, shows disappearance of both the suprasellar tumour and the deformation of the third ventricle (Fig. 34). A prolapse of the air filled suprasellar cisterns down into the sella is observed.