ANATOMICAL COMMENTS ON PSYCHOSURGICAL PROCEDURES.*

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There has recently been a plethora of new methods of psychosurgery. This has, we believe, created considerable bewilderment in the minds both of the clinical psychiatrists who have to decide which of the methods to choose and of the neurosurgeons who have to practise them. The aim of the present paper is to clarify and disentangle the situation as far as this can be done from the anatomical angle.

The different operations may be divided into three groups: leucotomies, cortical ablations, and miscellaneous.

Within the first group, the leucotomies, one may usefully distinguish, at the one extreme, methods based only on external measurements; the wholly blind operations. These include the older orthodox methods of prefrontal leucotomy, still the most commonly used, and transorbital leucotomy. At the other extreme are the leucotomies under direct visual control; the open methods, such as the operation introduced by Lyerly (1939) and elaborated by Poppen (1948 *a*,*b*); McKissock's (1949) modification of it, a rostral leucotomy, and Scoville's (1949) method of undercutting which, as far as one can judge, should be very similar to McKissock's operation in its anatomical effect. In between the blind and the open methods may be placed certain devices such as the one advocated by Dax and Radley-Smith (1948) with approach from the temporal fossa and orientation by means of the blood vessels of the Sylvian fissure; then again, orientation by tapping the anterior horns with a ventricular cannula, by air ventriculography, or by post-operative contrast radiography.

The second group comprises the operations, all of them open, which entail resection of cerebral cortex. This may be total prefrontal lobectomy, as practised by Peyton and his associates (1948), or partial ablation as in Penfield's (1948) gyrectomy and in the topectomy of the Columbia-Graystone associates (Heath and Pool, 1948*a*, *b*; Pool, 1949), which has been adopted, with minor modifications, by several French neurosurgeons (Le Beau, 1948; Le Beau, Feld and Bouvet, 1948*a*, *b*; Feld and Messimy, 1949; Puech, 1949).

In the last group the most important method is thalamotomy, introduced by Spiegel and his associates (1947) and employed occasionally by Puech.

It is the *blindness* of the usual operation that must be held responsible for the unintentional variability in the surgical cuts so consistently demonstrated in our now large number of brains derived from leucotomised patients (Meyer and McLardy, 1949). Due allowance must be made, of course, for the fact that we tend to receive a high proportion of the surgical failures, for differences of technique employed by different neurosurgeons and for deliberate intention. We were actually able to eliminate these last two variables in the

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case of, for instance, 21 brains operated on by the same neurosurgeon whose technique is highly standardised and whose skill is beyond question. He employs a cannulated leucotome to warn him if he trespasses upon the lateral ventricle—in which case he directs his instrument more rostrally before cutting. Yet in 10 out of the 21 cases the cut was so posterior, on at least one side, as to encroach upon structures posterior to the prefrontal region, whilst in two others the anterior horn was cut into within prefrontal precincts. That such cuts in too posterior a plane are dangerous was noted by Freeman and Watts as early as 1942, whilst the present writers (1948, 1949) have repeatedly shown how undesirable sequelae, such as restlessness, vasomotor and trophic lesions, persisting incontinence of urine, nutritional deficiency and respiratory disturbance, occur with significantly high frequency in cases with bilateral posterior cuts (i.e., cuts involving the posterior orbital region, the striatum and/or the premotor region), and seem to contribute to the occurrence of "delayed operative death" within five months of the operation.

From results of surgeons who have tried to improve the accuracy of the blind operation by other means, we can say that even preliminary location of the anterior horn by means of a ventricular cannula before inserting the leucotome is limited in effectiveness. Localisation of the anterior horns by means of a preceding air encephalogram might be more reliable, but although the method has been discussed, we have seen no published record of its systematic employment. Post-operative contrast radiography (by means of lipiodol, stainless steel wire or other contrast substance inserted into the cuts) still gives information only on the position of the cuts in relation to skull bearings, and, of course, only *post factum*. In a case* referred to us by Drs. Donovan and Galbraith and Mr. Jackson, an X-ray photograph (Fig. 1) was taken after a metal clip had been left in each cut. It showed the markers to be in front of the coronal suture. Dissection of the brain five months later showed that they were still situated in the leucotomy scars, but that these involved structures as far back as the putamen, one metal clip actually lying within putamen, internal capsule and caudate nucleus (Fig. 2). This is an example of the variability of the position of the coronal suture in relation to the underlying brain; a variability recently demonstrated impressively by Rowland and Mettler (1948).

Another interesting modification has been described by Dax and Radley-Smith, who approach the brain from the temporal fossa, gaining a limited orientation from the course of the blood vessels in the Sylvian fissure. These authors are satisfied that the procedure heightens the accuracy of the operation, but their method has not apparently been adopted by others; nor are pathological controls in sufficient numbers known to be available.

The foregoing considerations undoubtedly constitute some of the reasons why there has been such wide search for new methods—with outcome in thalamotomy, transorbital leucotomy, open leucotomy and cortical ablation.

Thalamotomy and transorbital leucotomy retain the defect that both are blind methods. *Thalamotomy* is performed by Wycis and Spiegel (1949)

* This case is included in a paper by Donovan, Galbraith and Jackson, since published in this Journal, July, 1949, **95**, 655.

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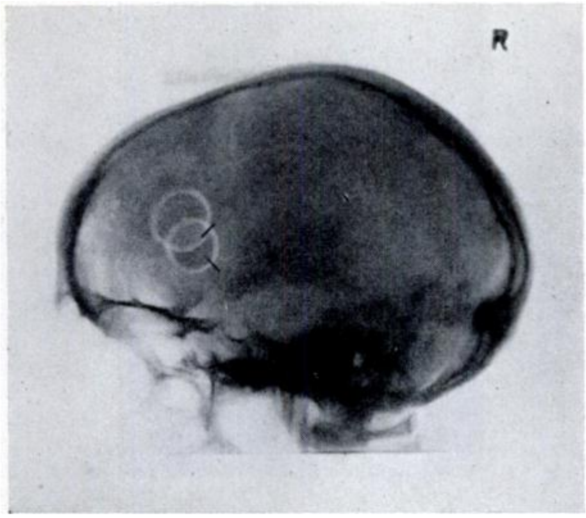

Fig. 1.—X-ray photograph, taken after operation, showing the position of the metal markers left in the leucotomy lesions.

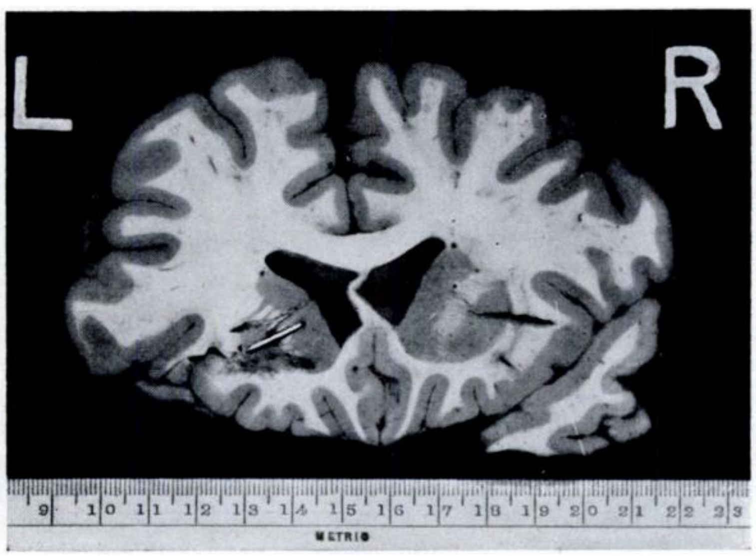

Fig. 2.—Position of the metal marker in the left leucotomy scar as seen after dissection of the brain.

with the help of a modified Horsley-Clarke instrument guided by prior location of the pineal gland by straight X-ray or air-encephalography. Even if it is possible to confine destruction with certainty to the dorsomedial nucleus, the parcellation of this nucleus in respect of its projection to the prefrontal cortex is such that even localised damage is liable to involve in addition the fibres projecting to a large part of the prefrontal region, thus rendering " individual

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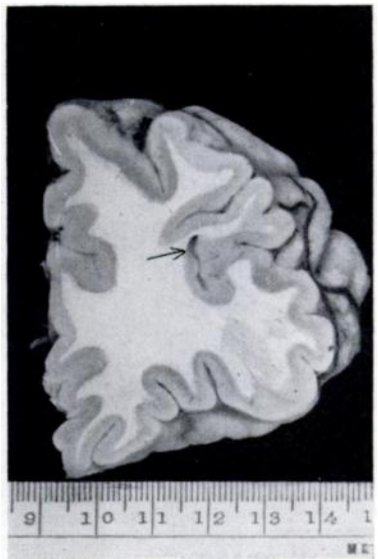

FIG. 3.—Punctate lesion (only) produced by the transorbitally inserted leucotome : lesion in other hemisphere was identical.

dosage" difficult. The method is undoubtedly of no small theoretical interest. It should, among other things, enable a decision to be reached as to whether interference with the thalamo-prefrontal projection system alone is the all-important factor in psychosurgery of the frontal lobes; but those who advocate minimal localised interference will, we judge, find thalamotomy too diffuse.

The halo of novelty which surrounds *transorbital leucotomy*, and its technical simplicity, make one sometimes forget that this is still a blind operation and that—so far—the only published report on the actual extent of the lesion produced in the brain has been that of Freeman, in 1948, which was based upon a cadaver operation. Through the kindness of Dr. Walsh of Tone Vale Hospital we were able to study the extent of the cut in one of two patients who died of intercurrent disease several months after transorbital operation. The other case was investigated by Dr. Norman in Bristol, who told us that the damage was identical with that in ours (which he inspected). According to Dr. Walsh (who will probably publish these cases in detail)* the leucotomies were performed with the instrument recommended by Freeman. In both brains the entry mark of the instrument is to be seen clearly on each side, in a position slightly more anterior than in Freeman's cadaver specimen. Within the brain substance itself, inspection revealed only punctate lesions (Fig. 3) and nothing that could be interpreted as the result of a medio-lateral sweep, although Dr. Walsh assures us that such a movement was definitely carried out in the way demonstrated by Freeman. Whatever may be the explanation, these two brains undoubtedly demonstrate again that in blind operations there is liable to be unpredictable variation in the extent of the

* Now published in *Lancet*, 10 Sept., 1949, **2**, 465.

lesions, the danger in transorbital leucotomy being of cutting too little and too anteriorly rather than too much and too posteriorly (at least in the "original" transorbital method as distinct from the new "deep cut"; Williams, 1949).

There remain for discussion the *open operations*, represented on the leucotomy side by the Poppen operation and on the resection side by Pool's topectomy. It is not always remembered that between leucotomy and resection there is a fundamental difference which may well have profound clinical significance, namely, that in the one only the fibres connecting with the nerve cells are severed, whilst in the other the nerve cells themselves are removed. It is known that the cortex anterior to leucotomy incisions remains histologically practically normal. The electroencephalogram after a period ranging from three weeks to three months(which probably covers the period of active repair) often returns to a relatively normal pattern. Potentially, therefore, this cortex may, by means of uncut fibres or pre-existing or newly-established subcortical or intracortical pathways, come under diencephalic influence again. This cannot happen when the cortex itself is removed. McLardy and Davies (1949) have discussed this difference in relation to the problem of relapse. It may well be that the ablation of prefrontal cortex, in sufficient amount, provides greater immunity from relapse than the mere cutting of its long fibre connections.

Poppen's open leucotomy consists in essence of a dorsal approach through a 2·5 cm. diameter trephine hole with its posterior brim bordering on the coronal suture, and bloodless cutting of white matter with a suction-cautery under direct illumination from a spatula fitted with a torch. From his recent impressive report on 470 operations (with only five deaths), and from personal descriptions by Mr. Falconer and Mr. McKissock, we have little doubt that this form of leucotomy offers a very large measure of precision and safety and, in addition, a maximum of flexibility in placing the cut according to the estimated requirements of the individual case. The rostral leucotomy of McKissock is, essentially, an anterior variation of Poppen's method, and has been devised to cut approximately the same anterior part of the prefrontal white matter as aimed at in transorbital leucotomy. Scoville has recently added another modification of the Lyerly-Poppen method by making the (dorsal) skull opening in a more anterior position, with its posterior brim 2 cm. in front of the coronal suture, and by abandoning suction and electro-cautery in favour of cutting.

Finally, circumscribed *cortical ablation*. This method commends itself to psychiatrists in virtue of its apparent cytoarchitectonic accuracy. This apparent accuracy, however, demands very considerable qualification from the anatomical point of view. The specific cytoarchitectural areas which it is the intention to ablate in topectomy are nicely mapped out in Brodmann's chart, but this and other charts commonly used take no account of individual differences, though the existence of such has been noted by various authors in the human brain and stressed in the macaque brain (Lashley and Clark, 1946). Moreover, the boundaries of the areas are by no means apparent in the brain on which the neurosurgeon operates, no matter how full the exposure. Nor are there any landmarks on the frontal lobe within reasonable reach of the neurosurgeon which might enable him to deduce the position of the cyto-architectural areas. Even a precise frontal pole is oftener than not impossible to define on the flat frontal curve. Hence, other, indirect landmarks have been suggested. Le Beau and Puech and their associates describe how they determine the junction of areas 9 and 10 either by drawing a line to the convexity at right-angles to the sylvian fissure, or by ascertaining the point which is 7 cm. from the coronal suture and 5 cm. from the "platform of the orbit" (see Fig. 3 of the paper by Le Beau, Feld and Bouvet, 1948*a*). We wish to stress that none of these landmarks is at all reliable. The substantial variability of the coronal suture in relation to underlying brain regions has, as already mentioned, been demonstrated very forcefully by Rowland and Mettler. It is very doubtful whether the slope of the Sylvian fissure, especially of the small fraction exposed, is of a consistency sufficient to warrant its use as a baseline. Even a slight aberration, or misjudgment, of it must lead to a formidable error in locating a point some 9 cms. distant along a perpendicular to it. The most reliable of the three landmarks appears to us to be the orbital plate, but, as we have confirmed in a number of skulls, the orbital plate slopes down some 2 cms. medialwards from its summit, and the French neurosurgeons do not state from what part of the orbital plate they took their measurements. (If one takes the level of the foramen caecum, situated at the junction of the crista gallica and the median ridge of the frontal bone, as a constant fixed bony point, the most antero-medial part of the frontal fossa, i.e., the tip of the cribriform plate of the ethmoid, lies about 1 cm. below it, and the summit of the orbital platform about 1 cm. above, and 3 cm. lateral to it.) Quite apart from the unreliability of these three landmarks, it has never been confirmed anatomically that any of them does in fact lead one to the desired cyto-architectural area of cortex.

In an attempt to obtain more reliable measurements we have begun to make systematic cyto-architectural investigations of the frontal lobes in normal brains, and give below a summary of our results so far in six hemispheres. These results, it must be emphasised, do not yet meet statistical requirements for validity, but they at least amplify the present scanty data furnished by Brodmann and others. For the purpose of this investigation we have divided the medial half of the frontal lobe into three sagittal blocks. Block III is the most medial, Block I the most lateral, and in between lies Block II (about 1½ cm. from the mesial surface) from which the diagram in Fig. 4 has been made. In view of Lashley and Clark's warning that swelling and shrinkage may be so formidable and variable as to lead to considerable error if unheeded, each brain was measured fresh as well as at the end of fixation, and all measurements from stained sections corrected (as in this diagram) so as to apply to the size of the fresh brain as seen by the surgeon. As the fixed point from which to take the measurements we chose the point on the frontal pole* which is at the level of the foramen caecum.

* This point on the frontal pole was determined in the six hemispheres without knowledge of the skull data. As has been mentioned it lies one centimetre above the tip of the cribriform plate. Since the latter in turn corresponds with the tip of the olfactory bulb, the point one centimetre ahead of the olfactory bulb on the fresh isolated brain gives the position of our fixed point. We have had opportunity to check this fact at post mortem in two brains.

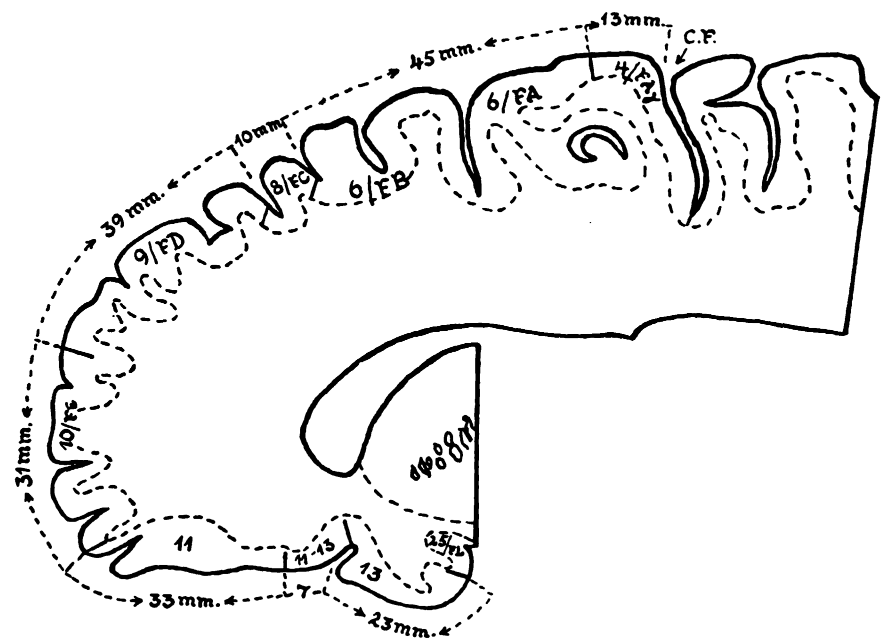

FIG. 4.—Normal 1. Right hemisphere. Projection diagram of sagittal block II showing the surface length of each Brodmann/von Economo area. The level of the foramen caecum in this particular block coincides with the junction of areas 10 and 11. (× 9/10 original size.)

In the hemisphere represented in the diagram the sagittal surface distance from the level of the foramen caecum to the junction of areas 9 and 10 is 31 mm., from there to the beginning of dysgranular area 8 is 39 mm.; from area 8 to the beginning of agranular area 6 is 10 mm.; and from there to area 4 is 45 mm. On the orbital surface the distance from the fixed point to the end of the granular portion of area 11 is 33 mm.; then follow 7 mm. of dysgranular transitional cortex and 23 mm. of agranular cortex, now known as area 13. It will be noticed that the distance of 31 mm. from the level of the foramen caecum to the junction of areas 9 and 10 is some 2 cm. less than the measurement used by Le Beau and Puech. This might be partly due to the French surgeons, as already mentioned, taking their measurements in a more medial plane where the frontal fossa sinks 1 cm. below the foramen caecum. In Table I, showing the measurement of this distance in each of the three blocks in all six hemispheres, values more approximating to 5 cm. do in fact, occur in the third (*i.e.*, most medial) block. This same table shows that individual variations in the position of the junction of areas 9 and 10 are quite considerable, differing even within the more constant medial Block III by as much as 2 cm. (*i.e.*, 37 per cent. in Left hemispheres and 38 per cent. in Right hemispheres).

These individual differences are not confined to the position of the junction of areas 9 and 10. In the graph shown in Fig. 5 we have tried to bring out the individual variation, as well as left-right variation in these three normal brains, by expressing the sagittal surface length of each area in proportion to a total frontal cortex of 200 mm. length, and by relating them to the foramen caecum

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TABLE I.—*Sagittal surface length (shown in mm.) of the dorsal portion of area* 10/FE (*i.e., from the level of the foramen caecum to the junction with area* 9/*FDm*).

	LEFT.	Maximal Individual Variation in %.	RIGHT.	Maximal Individual Variation in %.
Normal 1—				
Block I	38		28	
Block II ..	40		31	
Block III ..	31		31	
Normal 2—				
Block I	27	(I) 29%	42	(I) 38%
Block II ..	37	(II) 23%	51	(II) 39%
Block III ..	—	(III) 37%	50	(III) 38%
Normal 3—				
Block I	33		26	
Block II ..	48		31	
Block III ..	49		50	

as baseline. That there are considerable differences in which all granular regions participate, both as between left and right and different individuals, is obvious. It is also clear that in some instances area 10 is totally or almost totally dorsal to the level of the foramen caecum, whilst in others it extends considerably ventral to it on to the orbital surface. It may be added that in all six hemispheres the granular cortex was found to extend more posteriorly in Block II than in either (the lateral) Block I or (the medial) Block III. This is in agreement with both Brodmann's and von Economo's findings.

These individual differences have, so far, been investigated only in respect of the antero-posterior length of areas. It may well be that the differences would be found reduced or exaggerated if full investigation in other diameters were carried out. Again, as Lashley and Clark and others have pointed out, the architectural differences within the granular prefrontal cortex are not so striking as to preclude considerable subjective errors in delineation. In an attempt to minimise this difficulty all the cytoarchitectural measurements have been checked independently by two of us. The subjective differences in parcellation encountered would not seem sufficient to explain away the differences shown in the graph. A much larger material, now under investigation, is, however, necessary to render the differences statistically valid. At present all that is intended is to demonstrate that any claim by surgeons that specific areas have been removed is a far from accurate statement. No matter how precise his bony landmarks or his electrical definition of agranular cortex, the surgeon can never tell the extent of granular areas 9, 10, 11 and 46, in any particular brain, or hemisphere. Some of the surgeons performing topectomy are well aware of this, but cytoarchitectonic pseudo-accuracy has had a considerable appeal to a wider psychiatric public, particularly because it has been employed in the concept of localisation of mental function. Kleist's well-known map is now recognised to be too atomistic, but his influence is

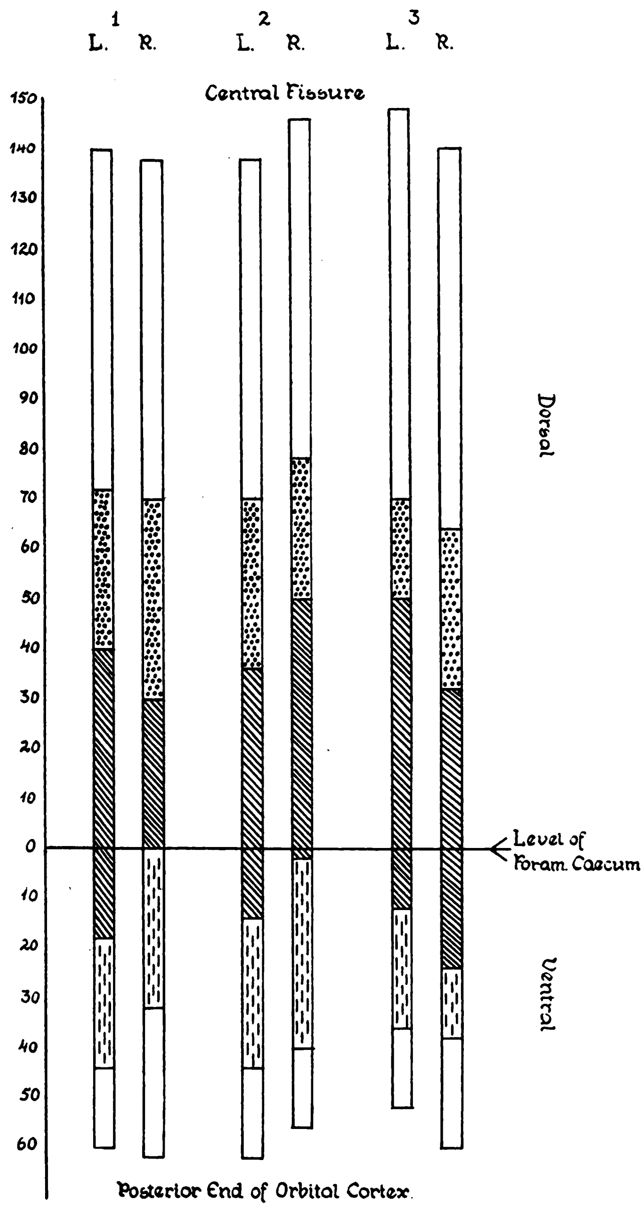

FIG. 5.—Graphic Representation of Individual Variation and of Left/Right Variation in Three Normal Brains.

(Expressed in proportion to a total frontal cortex of 200 mm. length, which approximates the absolute length in all cases.)

Area 10/FE = [hatched] Area 9/FDm = [dotted] Area 11/FF = [dashed]

FDC
Agranular + dysgranular areas = [blank]

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still alive. Our own studies of the problem (Meyer and McLardy, 1949; McLardy and Meyer, 1949) point to a slight preponderance of the orbital region in causing personality change and improvement, but apart from this we found in our anatomical material of over 60 cases with adequate survival, little encouragement for a rigid localisation of lesions in respect of either personality change or of clinical improvement. Several of our cases with the euphoric type of personality change had bilateral orbital damage, but others with typical fatuous euphoria had cuts which excluded these regions. Conversely, although several cases with the akinetic type of personality change had bilateral dorsal cuts, many others with such a personality change had no involvement whatever of the dorsal segments. These findings suggest that it is not so important that specific areas be removed, as that the amount of prefrontal cortex ablated be sufficient for the estimated requirements of the individual patients.

TABLE II.—*Sagittal surface length (shown in mm.) of granular and agranular frontal regions* (c.f. Fig. 4).

	Left.				Right.			
	Ventral Agranular	Ventral Granular	Dorsal Granular	Dorsal Agranular	Ventral Agranular	Ventral Granular	Dorsal Granular	Dorsal Agranular
Normal 1 ..	16	44	71	65	30	33	70	68
Normal 2 ..	18	44	71	68	15	40	78	64
Normal 3 ..	16	34	68	73	20	36	62	71

The most important point is that agranular and even dysgranular cortex be not infringed upon, because, as we have mentioned earlier, undesirable sequelae appear to depend much on the involvement of the agranular cortex, perhaps because it is so much concerned with autonomic control. In Table II we have set out the sagittal surface length of the granular and agranular—plus—dysgranular dorsal and ventral frontal cortex in the six normal hemispheres. In the case of granular cortex measurements were taken from our " fixed point." There are again individual differences, although not of the same magnitude as the variations within the granular frontal cortex. The lowest figure for granular cortex so far on the convexity is 62 mm.; on the orbital surface 33 mm. That is to say, ablations within these figures would, if our figures were statistically valid, be entirely safe in the average adult brain. These figures, it should be noted, are considerably smaller than those estimated by Le Beau and Puech, but agree better with Pool's (1949) most recent measurements. The usual topectomy cut does not extend down to the orbital surface. It might well be worth exploring whether inclusion of its anterior half might not improve the results. Previous disappointing results with exclusively orbital ablations might be due to the fact either that the lesions infringed upon dysgranular cortex within the posterior half of the orbital region, or that the total amount of prefrontal cortex removed was simply too circumscribed.

In conclusion, there is a definite tendency away from the blind and extensive leucotomies towards operations carried out under full vision and restricted in size and position according to the estimated requirements of the individual case. Anatomical considerations have had a considerable formative influence on this development. The two types of operation which in our opinion deserve an extensive trial are, firstly, leucotomy under full vision as practised by Poppen, Scoville and McKissock,and secondly, topectomy of granular frontal cortex. The fundamental difference between the two types of operation is that the one is a cutting of white matter fibres, the other a removal of cortical grey matter. This difference may or may not prove to be of clinical significance. The cytoarchitectural accuracy of the topectomies, often said to be their chief asset, has to be considerably qualified in the light of recent architectonic studies, including our own preliminary results.

Summary

The various psychosurgical operations are classified and reviewed from the the anatomical angle.

The two types of operation most deserving of extensive trial are considered to be leucotomy under full vision and topectomy of granular frontal cortex.

The inaccuracy of cytoarchitectural topography is demonstrated by the variabilities shown within the frontal lobes of six normal human hemispheres so far investigated by the authors.

The foramen caecum is suggested to be a relatively reliable fixed point from which to take rostral cortical measurements.

Acknowledgments

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References

Dax, E. C., and Radley-Smith, E. J. (1948), *Brit. J. Surg.*, **36**, 74.
Feld, M., and Messimy, R. (1949), *Presse méd.*, 26, 358.
Freeman, W. (1948), Med. Ann. Dist. Columb., **17**, 257.
Idem and Watts, J. W. (1942) *Psychosurgery*, Springfield.
Heath, R. G., and Pool, J. L. (1948a), *J. nerv. ment. Dis.*, **107**, 411.
Idem (1948b), *Psychosomat. Med.*, **10**, 254.
Lashley, K. S., and Clark, G. (1946), *J. Comp. Neurol.*, **85**, 223.
Le Beau, J. (1948), *La Semaine Méd.*, **60**, 1937.
Idem, Feld, M., and Bouvet, M. (1948a), *Rev. Neurol.*, **80**, 481.
Idem (1948b), *La Semaine Méd.*, **60**, 1942.
Lyerly, J. G. (1939), *South. Surg.*, **8**, 426.
McKissock, W. (1949), *Brit. med. J.*, **2**, 84.
McLardy, T., and Davies, D. L. (1949), *J. Neurol., Neurosurg. Psychiat.*, **12**, 231.
McLardy, T., and Meyer, A. (1949), *J. ment. Sci.*, **95**, 182.
Meyer, A., and McLardy, T. (1948), *ibid.*, **94**, 555.
Idem (1949), *ibid.*, **95**, 403.
Penfield, W. (1948), *Res. Pub. Ass. Res. nerv. ment. Dis.*, **27**, 519.
Peyton, W. T., Noran, H. H., and Miller, E. W. (1948), *Amer. J. Psychiat.*, **104**, 513.
Pool, J. L. (1949), *Digest Neurol. Psychiat.*, **17**, 432.
Poppen, J. L. (1948a), *J. Neurosurg.*, **5**, 514.
Idem (1948b), *Digest Neurol. Psychiat.*, **16**, 403.
Puech, P. (1949), *Presse méd.*, **8**, 115.
Rowland, L. P., and Mettler, F. A. (1948), *J. comp. Neurol.*, **89**, 21.
Scoville, W. B. (1949), *Digest Neurol. Psychiat.*, **17**, 431.
Spiegel, E. A., Wycis, H. T., Marks, M., and Lee, A. J. (1947), *Science*, **106**, 349.
Williams, J. M. (1949), *Digest Neurol. Psychiat.*, **17**, 415.
Wycis, H., and Spiegel, E. A. (1949), *Digest Neurol. Psychiat.*, **17**, 435.