4. It follows direct trauma of the chest wall or lung, and surgical operations on the abdomen, even remote from the diaphragm.

5. It gives definite physical signs, which may simulate pneumonia or pleural effusion.

6. The differential diagnosis depends on determining the position of the apex beat and the diaphragm.

7. It may, in cases of injury, affect the lung on the side remote from the trauma.

8. Its occurrence, whilst of itself not necessarily of grave import, yet places another burden on a patient already struggling with injury or disease.

9. Treatment should be preventive.

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ON THE POSSIBILITY OF RESTORING MOVEMENT TO A PARALYSED VOCAL CORD BY NERVE ANASTOMOSIS.*

(An Experimental Inquiry.)

BY

LIONEL COLLEDGE, M.B., F.R.C.S.,

SURGEON, EAR AND THROAT DEPARTMENT, ST. GEORGE'S HOSPITAL.

THE following series of experiments were carried out by Sir Charles Ballance with the collaboration of the writer. The experiments were performed at the National Institute for Medical Research, Hampstead, and were made possible by the facilities granted by the Medical Research Council. Although final conclusions have not been reached, certain definite results have been obtained, and it is at the suggestion of Sir Charles Ballance that this description of the research has been written.

Experiments on the effects of an anastomosis of the recurrent laryngeal with another nerve by previous observers do not appear to have given very definite results, probably owing to the difficulty of accurate observations on the movements of the vocal cords in animals without killing them at the end of the experiment. This is now easily overcome by using a direct vision laryngoscope. The larynx of a monkey and the movements of the vocal cords can be not only seen but carefully studied through the spatula of Chevalier Jackson, employing the model designed for the child. Direct observation has therefore taken the place of inferences drawn from the presence or absence of such symptoms as stridor, hoarseness, or roaring in animals. It has even been possible, although certain technical difficulties had first to be overcome, to record the movements of the vocal cords on a cinematograph film.

The results of the experiments may be divided into three groups.

I.—ANASTOMOSIS WITH THE VAGUS.

The first nerve employed was the vagus. Chevalier Jackson, in his book on endoscopy, suggests that an anastomosis between the vagus and the recurrent laryngeal might cure paralysis of a vocal cord. Since the recurrent laryngeal nerve passes down the neck in the trunk of the vagus, such an anastomosis would be most likely to succeed if the cut end of the recurrent laryngeal were united to that part of the vagus which contains the fibres of the recurrent laryngeal, before they have left the main trunk. There is, however, no means of distinguishing the fibres of the recurrent laryngeal from the rest of those which form the trunk of the vagus, so that there would be only a small chance of effecting such a reunion.

* An illustrated article by Sir Charles Ballance on experiments in which the facial and recurrent laryngeal nerves were anastomosed with other nerves was published in the *JOURNAL* (1924, vol. ii, p. 349).

Actually the end of the recurrent laryngeal was implanted into the side of the vagus in two goats, a rhesus monkey, and a baboon; but the last animal died of pneumonia three weeks later, which suggests that the operation may not be devoid of risk. There were therefore three effective experiments in this group.

In a large male goat the vagus was nearly half divided and the cut recurrent laryngeal sutured to the proximal lip of the incision. At the end of ten months no movement of the vocal cord had been observed, though it appeared to have become straight and tense. This effect, however, may have been produced by contracture of the intrinsic muscles of the larynx rather than by the return of the muscular tone. On exposing the anastomosis the recurrent laryngeal was found kinked and involved in scar tissue, nor was any movement of the cord produced by stimulation of the trunk of the vagus, the anastomosis, or the recurrent laryngeal itself. The experiment repeated on a young goat gave negative results at the end of six months.

In the rhesus monkey the same operation was done and the corresponding vocal cord was seen to be paralysed. At the end of four months no movement had returned though the cord was more tense. The anastomosis was exposed at the end of seven months, and abduction of the paralysed cord was obtained by stimulation (a) of the trunk of the vagus, (b) the site of the anastomosis, and (c) the recurrent laryngeal nerve.

The excursions of the cord were not quite so wide as on the sound side.

It appeared, therefore, that the muscles were innervated from the vagus, although no spontaneous movement occurred, and Professor Starling suggested that if the animal were partially asphyxiated the forced inspiration so produced might be so powerful that the muscles would receive a strong enough nervous impulse to cause a contraction. This experiment was tried at the end of nine months, and the cord was seen to abduct several times, though not so widely as on the opposite side. The same effect was seen at the end of twelve months, but was less after fifteen months, and has disappeared after seventeen months, and still has not reappeared.

It may be concluded from these experiments that, although a nervous connexion may be re-established by a recurrent laryngeal vagus anastomosis, it is useless to expect return of spontaneous movement in the corresponding vocal cord.

II.—ANASTOMOSIS WITH THE DESCENDENS NONI.

In another series of experiments the recurrent laryngeal nerve was anastomosed end-to-end with the descendens noni. This operation was done on four rhesus monkeys.

In the first experiment the recurrent laryngeal was anastomosed end-to-end with the descendens noni and the distal end of the descendens noni implanted into the side of the hypoglossal. Before the suture was completed it was observed that stimulation of the distal end of the recurrent laryngeal caused abduction of the cord. This animal died from bites received from another monkey six weeks after the operation, so that no result was obtained.

In the second experiment the same operation was done on the right side, except that the distal end of the descendens noni being very small was left free. At the end of two months there appeared to be increased tension in the cord but no spontaneous movement. Stimulation of (a) the hypoglossal proximal to the origin of the descendens noni, (b) the descendens noni, (c) the anastomosis, all caused abduction of the cord, showing that a nervous impulse could pass through the anastomosis. At the end of four months there was still no spontaneous movement in the cord, but on partial asphyxiation abduction of both cords followed but soon ceased. At the end of five months, and again at the end of seven months, there was still no movement of the cord on tranquil respiration, but wide excursions of both cords followed partial asphyxiation and lasted for two minutes. The movements of the right cord gradually ceased as the effects of the asphyxiation passed away. The animal became ill at the end of nine months and was killed, but it was noted that still there were no spontaneous movements of the right cord.

In the third experiment the animal had to be killed at the end of seven months; the results were exactly the same as in the second experiment.

In the fourth experiment the descendens noni was anastomosed end-to-end with the recurrent laryngeal. The distal end of the descendens was implanted into the side of the phrenic. No spontaneous movement returned to the vocal cord, but when the animal was killed at the end of three months stimulation of (a) the hypoglossal proximal to origin of the descendens noni, (b) the descendens noni, and (c) the anastomosis, all caused abduction of the vocal cord.

The results of these experiments with the descendens noni show that, as in an anastomosis with the vagus, the muscles controlling the movements of the vocal cord become innervated, but no movement occurs in the cord because the appropriate impulse does not pass along this route.

It is probable that when the animal swallowed, an associated movement of the vocal cord occurred, for at that moment an impulse would be travelling down the descendens noni, but no means of making this observation satisfactorily could be devised.

Dr. Frazier of Philadelphia,¹ at the request of Dr. Chevalier Jackson, performed an anastomosis between the recurrent laryngeal and the descendens noni in two patients with vocal cord paralysis. The results of these operations were the same as those on the monkeys. Tension returned to the paralysed cord, but no spontaneous movement. Descendens noni-recurrent laryngeal anastomosis is therefore useless for the relief of paralysis of the vocal cord.

III.—ANASTOMOSIS WITH THE PHRENIC.

It appeared that if the vocal cord could be linked up with the muscles of respiration, then a rhythmical impulse rightly timed would pass through the anastomosis and might restore the normal movements of quiet respiration to the cord. In this case, in contrast to the dissociated movement required for the cure of facial palsy, an associated movement with the respiratory muscles would be desirable.

In the third series of experiments, therefore, the recurrent laryngeal was anastomosed to the phrenic to obtain associated movement between the vocal cord and the corresponding half of the diaphragm. In this series six experiments were performed on three baboons, a hussar monkey, and a rhesus. In one baboon, which died at the end of the fourth month, the recurrent laryngeal was implanted into the side of the phrenic, which apparently had only one root coming from the fourth cervical nerve. In another, which died at the end of a month, the recurrent laryngeal was anastomosed end-to-end with the root of the phrenic arising from the fourth cervical nerve. In neither case had any movement been restored to the cord when the animal had to be killed.

There remained, therefore, four effective experiments.

The first experiment was performed on a baboon. The right recurrent laryngeal was anastomosed end-to-end with the phrenic, and, with the object of restoring the movements to the diaphragm, the distal end of the phrenic was united to the central end of the descendens noni, and the distal end of the descendens noni implanted into the side of the hypoglossal. Stimulation of the recurrent laryngeal during the experiment caused abduction of the paralysed cord, and of the phrenic caused contraction of the diaphragm. At the end of two and a half months no movement was observed in the right vocal cord. At the end of four months the vocal cords were observed to move equally during quiet respiration. The adductor spasm caused by partial asphyxiation was followed by abduction of both cords, but the abduction was a little greater on the left (normal) side than the right.

At the end of six months the cords moved symmetrically, but the excursions of the right cord were now wider than those of the left (normal) cord. At this time the left recurrent laryngeal was anastomosed end-to-end with the left phrenic, thus paralysing the left vocal cord, whilst the right continued to act through the right phrenic. At the present time slight abduction can be observed in the left cord, but, probably owing to some injury to the neck during the administration of an anaesthetic, the right cord has again become paralysed.

These two experiments, however, show that anastomosis with the phrenic is capable of reproducing the normal movements of the vocal cords in tranquil respiration.

In a hussar monkey the phrenic was exposed and separated into two bundles, one of which was divided and anastomosed end-to-end with the distal end of the recurrent laryngeal. This animal shows only the slightest movement of abduction after ten months, and even this disappears altogether under a deep anaesthetic. On partial asphyxiation, however, adductor spasm of both cords occurs.

In a rhesus monkey the distal end of the right recurrent laryngeal was implanted into the side of the phrenic. At the end of two months the right cord was still paralysed, but it appeared to have become more tense than immediately after the operation. At the end of three months there was still no spontaneous movement, but on partial asphyxiation the adductor spasm was followed by abduction of both cords which soon ceased in the right. At the end of seven months both cords were observed to be moving during tranquil respiration, but the excursions of the right cord were not so wide as those of the left.

It may be noted that the movement of adduction, induced by partial asphyxiation, reappears before that of abduction, which corresponds to the weaker extensor movement in the limbs. This is in keeping with the disappearance of abduction earlier than adduction in paralysis of the vocal cords, supervening slowly under pathological conditions.

It is shown from these experiments that spontaneous respiratory movements can be restored to the vocal cord by an anastomosis between the recurrent laryngeal and the phrenic. The entire trunk of the phrenic is not necessary, and probably it will be found sufficient to use half the trunk, as in a lateral anastomosis, or one of the roots arising from the cervical nerves.

No case has so far presented itself in which an operation for the relief of a paralysed cord appeared justifiable in the human being, but if such should be undertaken it is suggested that the appropriate operation would be an end-to-side anastomosis between the recurrent laryngeal and the phrenic.

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SPINAL ANAESTHESIA BY STOVAINE.

BY

ROBERT B. COLEMAN, M.B., CH.B. BIRM.,

CHURCH MISSIONARY HOSPITAL, OLD CAIRO, EGYPT.

In the Church Missionary Society's Hospital in Old Cairo, Egypt, spinal anaesthesia is now used as routine in all suitable operations by all the five surgeons on the staff. A beginning was made about eight years ago, when this method was used in a certain number of picked cases. It took some time for it to become popular with more than one or two of the surgeons, and the Egyptian fellaheen patients were inclined at first to resent this new method, expecting to be given something to inhale, as all their relations and friends had told them was regularly done. Little by little its scope was increased, till by the end of 1924 it was used in every suitable case unless there was some contraindication.

Exact numbers of cases are not available, but they amounted to more than 5,000 down to February, 1925, and at the present time we are doing about 2,400 a year.

Solution Used.

Stovaine is the drug used. Tropacocaine was tried, but did not give quite such good results in our hands. I do not know the reason for this, as Professor Morrison of Birmingham, one of the pioneers in spinal anaesthesia, found it so satisfactory.¹ For some time the ampoules of stovaine billon were used, but later were discarded, chiefly on the ground of expense, and lately we have ampoules put up for us by Messrs. Parke, Davis and Co., as follows: stovaine 0.1 gram, sodium chloride 0.1 gram, sterile distilled water to 1 c.cm. They are sent out to us a thousand at a time, and have proved consistently satisfactory. Their simplicity seems to add to their efficiency.

Type of Case.

The following comparative summary of the last 2,000 cases covers a period of about ten months, and shows how varied are the operations included.

Abdominal sections (including splenectomy, gastro-enterostomy, intestinal anastomosis, appendicectomy, hysterectomy, ovariectomy, etc.)	58
Vaginal and uterine operations (colporrhaphy, perineorrhaphy, curetting, etc.)	121
For inguinal hernia	330
For hydrocele, varicocele, etc.	210
Lithotripsy	51
Suprapubic cystotomy (large stone, prostate, etc.)	43
Nephrectomy	3
For urinary fistula	57
For haemorrhoids	518
For rectal bilharzial papillomata	461
For fistula in ano, ischio-rectal abscess	112
Amputations	8
For injuries and various conditions	30
	2,000

It is only lately that the larger operations in the upper abdomen have been attempted by this method of anaes-