to be of at least 19 days' duration but probably as long as six weeks. The trial was designed to protect, but also to assess, the safety of the vaccine for both vaccinees and contacts. Since the epidemic was due to type 1 virus it would have been easy to detect cases due to type 2. In the light of our present knowledge of the safety of these vaccination procedures (Smorodintsev *et al.*, 1959 ; Chumakov *et al.*, 1959 ; Skovránek *et al.*, 1959) it would be generally agreed that now, faced with a similar incident, the vaccine of choice would be type 1.

Although interference between the enteroviruses was observed, no general pattern was evident. A prior infection might prevent the establishment of a second ; the second might be limited in such a way that no detectable antibody resulted ; or, further, the second virus might establish itself and apparently obliterate the earlier infection. In all probability the pattern that results is governed by the magnitude of the first infection, the length of time it has been present, and the magnitude of the second infection.

With attenuated poliovirus vaccine large doses such as 10^5, 10^6, or even 10^7 TCD50 are used, so that even in communities with a relatively high incidence of enteric virus infection quite good results might be obtained. Not all persons will have infection at the stage capable of interfering, and the dose of vaccine is so artificially large that it might overcome such interference. Also, in a mass campaign a child failing to become infected from the vaccine as a result of interference may become secondarily vaccinated by contact when its pre-existing enteric infection wanes.

The mass immunization with live poliovirus vaccine raises an interesting ecological possibility. It is considered that the live vaccine has a double effect: not only are antibodies produced but the intestinal tract is rendered resistant to subsequent invasion by the same type of virus. Therefore a highly immunized community might contain so few susceptibles that poliovirus circulation would probably cease. These conditions might free the field for infection with other enteric viruses, such as the E.C.H.O. group, resulting in a consequent rising incidence of conditions such as aseptic meningitis. With the disappearance of poliomyelitis, viral meningitis and encephalitis may become a much greater clinical problem.

Summary

Interference between enteric viruses was observed during the mass use of Sabin type 2 vaccine in Singapore in 1958. An established type 2 vaccine infection prevented subsequent infection with the type 1 epidemic strain for at least 19 days and probably longer. In some instances prior infection with the epidemic strain prevented colonization with the vaccine strain.

Interference effects were also observed in the trial in Newcastle upon Tyne. Administration of the three Sabin strains simultaneously as a single dose often resulted in failure of production of antibodies to types 1 or 3 and sometimes to both. Antibodies to type 2 were always produced.

An existing enteric virus infection sometimes prevented the establishment of an infection from the vaccine virus, but whether this occurred depended on the stage of the existing infection. Similarly, poliovirus circulation in a community suppressed the circulation of other enteric viruses.

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TREATMENT OF TETANUS

WITH SPECIAL REFERENCE TO TRACHEOTOMY

BY

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In the recent literature on the treatment of tetanus emphasis has been laid on intermittent positive-pressure respiration (I.P.P.R.) as the basic change in technique responsible for therapeutic improvement. But for I.P.P.R. an elaborate organization is required, and in many places neither the equipment nor the trained personnel were available. The value of tracheotomy alone has not been stressed, and the purpose of this paper is to describe the improved results that followed on the introduction of this simpler measure ; to define the indications for doing a tracheotomy, or for using I.P.P.R. ; and to outline the method of treatment which has been found most effective.

Tetanus is usually classified as severe if the incubation period is less than seven days, or if the period of invasion between the onset of the first symptom and the first generalized spasm is less than 48 hours (Cole, 1940). There are, however, exceptions to this rule, and it has been found more helpful to classify cases according to the severity of the spasms, with special reference to the effect of generalized spasms, laryngospasm, and pharyngospasm on respiratory function. Mild cases have no generalized spasms, only muscular hypertonicity. Moderate cases have generalized spasms, but these are not prolonged or frequent and do not interfere with respiration or swallowing. Severe cases have spasms that impair pulmonary ventilation in one or more of the following ways: prolonged or frequent spasms that fix the chest wall and diaphragm ; laryngospasm with complete obstruction of respiration ; and pharyngospasm which prevents the swallowing of saliva that lies pooled in the pharynx and is inhaled into the trachea. The impaired pulmonary ventilation is

manifested by anxiety, restlessness, a rising pulse rate and blood-pressure, sweating, and cyanosis. Very severe forms show signs of impending failure of the vital centres with circulatory collapse, respiratory failure, hyperpyrexia, ileus, coma, or diminished spasms with muscular flaccidity.

Any spasm severe enough to cause apnoea, which requires artificial respiration to re-establish breathing, is an important sign of impending respiratory failure, as in the pretracheotomy era a second attack of this type was invariably fatal. Occasionally severe forms are associated only with focal spasms of the larynx or pharynx (Courtois-Suffit and Giroux, 1918) which can also threaten life by obstructing respiration.

Material

Fifty-five children, excluding cases of tetanus neonatorum, were admitted to hospital with tetanus between 1951 and 1957. In many of these children the incubation period could not be accurately determined as either the history was unreliable or there were so many minor abrasions that it was impossible to decide from which site the infection arose. In 26 of them, however, the period of invasion was less than 48 hours. They were treated with intravenous and intramuscular tetanus antitoxin, penicillin, barbiturates, paraldehyde, and, in a few cases, chlorpromazine. Of these 55 children, 27 (49%) died.

Since 1958, 27 children with tetanus have been admitted to Groote Schuur Hospital and the Red Cross War Memorial Children's Hospital, of whom 14 had an invasive period of 48 hours or less. Tracheotomy was done in 14 cases and I.P.P.R. was used in four. Of the 27 children, 3 (11%) died.

Treatment

After desensitization by multiple injections of increasing strength if a routine intradermal test dose of 1 min. (0.06 ml.) of antitetanic serum was positive, all patients were given 30,000 units of antitetanic serum intravenously and 60,000 units intramuscularly. Wounds were treated solely on their surgical merits. Thickened skin was pared off and any wound examined carefully for the presence of a foreign body. Procaine penicillin was given daily for 10 days and then stopped. The sedatives used were paraldehyde and barbiturates, occasionally chlorpromazine, beginning with standard dosages and increasing until spasms were controlled. Recently mephenesin, in dosages of up to 150 mg./lb./day (330 mg./kg./day), together with phenobarbitone, has been given by stomach tube and appears to be more effective than other combinations of drugs.

Tracheotomy

Tracheotomy was done in all severe cases—that is, those with frequent or prolonged spasms; with laryngospasm; with pharyngospasm or any difficulty in swallowing; and in those showing signs of cardio-respiratory distress with a rising pulse rate, cyanosis, and sweating. It is always wiser to do the tracheotomy early rather than late, as even the first generalized spasm, especially if associated with laryngospasm, may end fatally. Much of the success of treatment depends on the technique of tracheotomy and the subsequent care of the patient. Tracheotomy is always done under general anaesthesia with an endotracheal tube passed. A very "low" tracheotomy has not been found entirely satisfactory. It requires a long tube, with an increased hazard in small children of the tube impinging on the carina. It also makes the insertion of a cuffed tube into the trachea more difficult. Furthermore, the longer the tube the greater is the likelihood that with head retraction during spasms the tip of the tube may be tilted upwards against the anterior tracheal wall, which will obstruct respiration and traumatize the trachea. It is our impression that very "low" tracheotomies are associated with a higher incidence of mediastinal emphysema and pneumothorax. There also seems to be greater difficulty when the tracheotomy tube has to be changed, and false passages are more easily made.

Initially, where size permits, a Radcliffe tracheotomy tube is inserted, because the course of tetanus is unpredictable and I.P.P.R. may be required for cases which at first appear only moderately severe. Even if I.P.P.R. is not used, the cuffed tracheotomy tube helps in preventing pharyngeal secretions from being inhaled into the lungs. The Radcliffe tube is left in for about 10 days, after which I.P.P.R. is unlikely to be required. It is then replaced by a metal tracheotomy tube. Frequent suctioning with a soft rubber catheter, obviously of small enough diameter not to impede respiration, should be started immediately after the tracheotomy as blood often runs down the trachea. Once bleeding has ceased, suctioning about every half-hour is sufficient, but it may have to be done more often if there is much secretion. It is essential that suctioning should continue until all secretions have been aspirated, but too high a suction pressure should be avoided as the tube may become attached to the tracheal wall and mucous membrane may be tugged off, causing bleeding.

Humidification must be started as soon as the patient returns from the theatre. Warm vapour is preferred to "alevaire" and must be dense enough to keep secretions loose. The need for adequate humidification cannot be too strongly emphasized, and failure to maintain adequate humidification is probably the most important cause of trouble with tracheotomies. With inadequate humidification, mucous secretions may become very tenacious and difficult to remove. When a metal tracheotomy tube is being used, the inner tube may be quite clean, but when it is reinserted sticky mucus may be scraped off the wall of the outer tube to form a plug at the tip of the tube, which obstructs respiration. For this reason tracheotomy tubes should be changed every four days. A few drops of trypsin inserted into the tube is effective in loosening inspissated mucus and blood. Free breathing should be checked, not only by auscultating the chest, but also by listening over the open end of the tracheotomy tube, where any obstruction to respiration can be heard as a wheezing sound. Even slight obstruction of the airway will increase spasms, and the inclination to increase sedation should be resisted until it is certain the air passages are clear, the tube is lying in alignment with, and not kinking, the trachea, and an *x*-ray film has excluded the possibility of the tube impinging on the carina.

The tracheotomy tube is removed only after the patient can swallow all feeds without difficulty and spasms have ceased to affect respiration. It is easier to wean a child from a tracheotomy if a small tube is inserted around which the patient can breathe, or else a tube with an opening in its upper wall which communicates with the larynx. The stoma of the tube

can then be occluded and the patient accustomed to normal breathing for some hours, after which the tube can be removed without difficulty.

Routine Care

Pulmonary infection has been most uncommon since tracheotomy allows aspiration of secretions from the trachea. Owing to the hypersalivation that seems to be a feature of severe tetanus and the pharyngospasm which prevents any swallowing, frequent suctioning of the mouth and pharynx is also necessary to limit the amount of saliva leaking into the larynx and trachea. The patient should be turned from side to back every four hours to encourage bronchial drainage. A rising pulse rate, sweating, fever, impaired air entry, and increasing spasms are far more likely to be due to mucus obstructing a bronchus and causing pulmonary collapse than to pulmonary infection. Routine antibiotic therapy is stopped after 10 days and subsequently given only if there is overt evidence of infection. Great emphasis is laid on a strict aseptic technique. Masks are worn, hands are washed before suctioning, and the rubber catheters are sterilized before being used again. Some infection tends to occur around the tracheotomy wound, but this appears to be lessened if no dressing is applied.

In all severe cases the patients were fed by a stomach tube which was passed through the nose during anaesthesia for tracheotomy. Otherwise very heavy sedation was required to overcome the spasm of the palate and pharynx, which makes passage of the tube very difficult. Extra fluids may be required as dehydration can follow a period when the patient has been unable to swallow, has sweated excessively, and has lost much saliva. Electrolyte losses in the saliva and sweat should be replaced. Milk feeds were given by stomach tube. As children are inclined to pull out the stomach tube it is necessary to restrain their arms. The stomach was aspirated before each feed in case ileus was developing, as vomiting may result in inhalation of stomach contents. Intravenous fluids were used in only two cases which developed ileus.

Traditionally, patients with tetanus are nursed in a darkened room free from noise. In adults this may be necessary, but our experience with children is that light and noise rarely provoke spasms. Tactile stimuli, however, do, and care should be taken in handling the child. Frequent suctioning of the mouth and trachea at short intervals may be preferable to prolonged suctioning as this is a potent cause of spasms. One child was of interest in that whenever he had a severe spasm of the neck he would cry out to the nurse to bend his head forward, which relieved the spasm. This suggests that spasms are to some extent self-perpetuating and that hyperextension of the neck and trunk should be prevented so far as is possible. While the patient is turned on his side pillows are used to keep the head forward as much as possible and to prevent excessive opisthotonos.

Fever seems to be part of the clinical picture of severe tetanus, but a rise in temperature may also be due to inadequate ventilation, dehydration, or infection. Active steps are taken to lower the temperature if it rises above 102° F. (38.9° C.). The patient is stripped and exposed, and if that does not lower the temperature a fan is made to blow on the body. Urinary retention is fairly common and may require catheterization. Constipation is the rule in severe cases, but while the child is on milk feeds no active steps are taken unless ileus develops, when intravenous fluids are given and gastric aspiration is carried out. Nurses should be told to report at once any change of condition, rise in pulse rate, sweating, or cyanosis, but this does not alter the fact that the outcome of this disease is largely determined by the frequency with which the medical staff check on the state of the patient.

Intermittent Positive-pressure Respiration

All cases are given a trial of sedation and tracheotomy, and only if this treatment fails, as judged by the occurrence of one of the following criteria, is I.P.P.R. started. (1) Spasms of such severity as to interfere with respiration and which cannot be controlled by sedation, or which require such heavy sedation as to depress respiration. (2) Respiratory failure due either to heavy sedation, or to brain-stem intoxication, or to cerebral anoxia, or to a combination of these factors. Respiratory failure may also be due to an overwhelming toxaemia causing a flaccid weakness of muscles. (3) Hyperpyrexia of over 104° F. (40° C.). (4) Increasing cardio-respiratory distress with a rising pulse rate, sweating, and cyanosis which, if allowed to persist, will go on to collapse.

The care of the patient on I.P.P.R. has been covered by a number of authors (Lassen *et al.*, 1954; Smith *et al.*, 1956), and it is only necessary to comment on a few minor points of difference. Generally, weaning from the pump was attempted at an earlier time than is customary. It is felt that the hazard of some mechanical or therapeutic failure is great enough while the patient is curarized and on I.P.P.R., and that attempts should be made to wean from about the tenth day. Spontaneous breathing is preferred even though the spasms are not yet fully abated. While the child is curarized no sedation is used as it is our impression that in most severe cases the patients are not conscious. None of the children had any recollection of what had occurred. All of them showed signs of recovering consciousness, however, before it was possible to stop I.P.P.R.

Recently a change in technique has been found which is effective in clearing the bronchi of secretions. The child is disconnected from the respirator and ventilated with an anaesthetic handbag. The chest is then alternately forcefully inflated and manually compressed in a cough-like manner. Secretions are brought up into the main bronchi and trachea, from where they can be sucked out with a catheter. A similar manœuvre while on the respirator seems only to increase the amount of pulmonary collapse. This suggests that the essential change is overinflation of the lungs, just as in a cough, which may dilate the bronchi, loosen secretions, and allow air to get behind the obstruction from whence, with a forced expiration, secretions are dislodged into the large bronchi.

The following case record is included to show the natural history of a severe case of tetanus treated with tracheotomy and sedation.

A boy aged 6 years was admitted to hospital on December 28, 1959. Fourteen days previously he had trodden on a rusty nail. For four days he had complained of pain in the back, abdomen, and jaw, and it was noticed that he had trismus. For 24 hours generalized spasms had increased in severity and frequency until they were occurring

about every one to five minutes, and on two occasions had been associated with cyanosis. The child had been unable to swallow because of a feeling of a lump in the throat. On examination his temperature was 104° F. (40° C.), pulse 160–170, and respirations 40. He was a conscious, co-operative boy with frequent generalized tetanic spasms lasting up to four minutes and causing cyanosis. Tracheotomy was done under general anaesthesia and a Radcliffe tracheotomy tube inserted. Phenobarbitone 65 mg. was given six-hourly and elixir of mephenesin 240 mg. hourly by stomach tube. Over the next two days these were increased to phenobarbitone 65 mg. four-hourly and mephenesin 360 mg. hourly. For the first week the temperature fluctuated between 100 and 103° F. (37.8 and 39.4° C.). On the third day the pulse fell to 130. Thereafter, on the eighth day the spasms were less severe; twelfth day, the amount of saliva suctioned from the mouth was lessening; fourteenth day, he was able to nod in assent, and saliva no longer exuded from the lips during a spasm; sixteenth day, mephenesin was reduced; eighteenth day, mephenesin was stopped. On the twentieth day the temperature finally settled and the stomach tube was removed. The tracheotomy tube was removed on the twenty-third day. At this stage phenobarbitone was reduced to 32 mg. six-hourly and was finally stopped after five weeks. He was discharged home after six weeks, having been given his first prophylactic injection of tetanus toxoid.

Tetanus does not confer active immunity and all cases on recovery should be actively immunized with tetanus toxoid.

Deaths

In the three children in our series who died the cause of death was quite clear. In one the tracheotomy tube appeared to be lying badly in the trachea from the onset. There was undue hesitancy about changing the tube as early as the day after operation, and when it was finally decided to do so the child died as the E.N.T. surgeon arrived. The second death was due to an occlusive tracheobronchitis. The third child died because a connexion worked loose on the fourteenth day just when he appeared to be recovering from very severe tetanus which had to be treated with I.P.P.R.

Discussion

In 1836 Thomas Curling first suggested that tracheotomy might help in the treatment of tetanus, although he never actually treated a case. The first recorded use of tracheotomy was by Humphry (1856); the patient, however, died.

Routine tracheotomy for severe cases was started about 10 years ago. Creech *et al.* (1950), having at first strongly recommended its use, subsequently (Creech *et al.*, 1957) were prepared to concede only a reduction of 10% in the mortality and thought that some of the decrease in mortality was simply a continuation in a trend that began 50 years ago. Adriani and Kerr (1955) were inclined to give credit to tracheotomy as having contributed most to the reduction in mortality (100 cases with 32 deaths). Both their mortality rates, nevertheless, are lower than in most reported series in which tracheotomy was not part of the routine therapy. Curling (1836) records a death rate of 54% of 128 cases; Johnstone (1958) 56% of 100 cases; Adams (1958) 44% of 100 cases; and Brown *et al.* (1960) 49% of 41 cases. Only Veronesi (1956), with the remarkable mortality of 18.2% of 236 cases, has achieved a low mortality without tracheotomy. In Capetown, Slome (1953) found a mortality of 43% in 137 cases treated between 1947 and 1952. The mortality of 49% in 55 cases in our series is in keeping with most other series without tracheotomy. In our opinion there has been little doubt that the dramatic fall in the mortality has followed upon the introduction of tracheotomy for severe cases. Even if the three survivors who were treated with I.P.P.R. are included in the failures the mortality is still only half that of the earlier series.

Tracheotomy, especially in small children, has the reputation of being a somewhat hazardous procedure. Undesirable results are likely to occur when it is done either too late or as an emergency under local anaesthesia and the operation has to be hurried because of respiratory obstruction. Then excessive bleeding, cerebral anoxia, and complications like mediastinal emphysema and pneumothorax are more likely to occur. When an elective tracheotomy is done under general anaesthesia with an endotracheal tube passed, it has been found a safe procedure at any age. Most trouble arises during the subsequent care and nursing because of inadequate humidification and suctioning, and from failure to observe any obstruction of the airway. It is noticeable that trouble rarely occurs with the tracheotomy tube while the patient is on I.P.P.R., presumably because the machine maintains good humidification.

There can be little doubt that tracheotomy is as rational a procedure for tetanus as it is for severe laryngeal obstruction and for head injury with coma where the patient cannot swallow his saliva. Furthermore, the effect on respiration of severe tetanus is much the same as in severe poliomyelitis with pharyngeal, laryngeal, intercostal, and diaphragmatic involvement except that the one is a spastic and the other a flaccid palsy. The main purpose of tracheotomy is to prevent the anoxia and hypercapnia associated with laryngospasm and retained pharyngeal secretions, and, by lessening the dead space, to make more effective breathing that is restricted by intercostal and diaphragmatic spasm. Anoxia potentiates tetanic spasms which demand heavier sedation until respiration is depressed with further increase in anoxia. Tracheotomy breaks this vicious circle. The effectiveness of tracheotomy in relieving anoxia and infection comes as no surprise when the amount of secretion aspirated from the trachea is seen at operation. The subsequent fall in the pulse rate, the reduction in the amount of sedative required to control spasms, the lessening of cyanotic attacks, and the rarity of pulmonary infection all testify to the effectiveness of the procedure. Furthermore, sudden death following on laryngospasm has not been seen since routine tracheotomy has been done.

Tetanus occurs most often in the underdeveloped areas of the world, where facilities for I.P.P.R. may not be available. Most hospitals, however, can deal with a tracheotomy, and if nursing facilities are limited the remarkable example of Adriani and Kerr (1955) can be quoted where "a member of the family is taught to suction secretions from the pharynx and trachea." If I.P.P.R. is available we still prefer a trial with tracheotomy and sedation, and resort to I.P.P.R. only when the indications are that this is likely to fail. While there should be no hesitation in instituting I.P.P.R. when it is required, it should be stressed that it is a worrying procedure by no means devoid of risk, particularly if nurses and resident staff are constantly being changed.

One other factor that may have played a part in the improved results in this series is the use of mephenesin as a relaxant. When combined with a barbiturate, it has

been found by Adriani and Kerr (1955) to be the most effective drug. First used in neonates, we have used it with success in the last seven older children. In three children treated with paraldehyde, phenobarbitone, and tracheotomy who were having such severe spasms that I.P.P.R. was contemplated, a change from paraldehyde to mephenesin resulted in satisfactory control. In adults it has been used intravenously rather than by mouth, but in children it has proved effective when given by stomach tube. Because of its local anaesthetic action this is preferable to oral administration, which may lead to depression of pharyngeal protective reflexes. It has shown none of the recognized complications of fall in blood-pressure, haemoglobinuria, or thrombophlebitis.

It cannot be too strongly stressed that tetanus is a preventable disease and that active immunization with tetanus toxoid is a safe procedure that should be carried out in all communities. The use of antitetanic serum in prophylaxis is far less satisfactory as it carries a considerable hazard from serum reactions. It has also been shown recently to be ineffective if the recipient has had horse serum or has an anaphylactic reaction (Godfrey *et al.*, 1960). Furthermore, severe and fatal tetanus can follow upon the most trivial injury for which the patient is unlikely to receive any prophylactic antitetanic serum.

Summary

In a series of 55 children with tetanus in which routine tracheotomy was not done, 27 (49%) died, while in a comparable group of 27 children in which tracheotomy was done in 14 severe cases and I.P.P.R. was used in 4, there were 3 deaths (11%). Apart from the use of mephenesin in some of the latter group, treatment was essentially the same.

Reasons are given why tracheotomy should be part of the routine treatment of severe tetanus.

The indications for and the technique and subsequent care of the tracheotomy in patients with tetanus are described.

Even if I.P.P.R. is available, it is felt that tracheotomy and sedation should be tried first, and only if this treatment fails, as judged by certain criteria, should I.P.P.R. be applied.

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AN INVESTIGATION OF SELECTIVE DEAFNESS PRODUCED BY DIRECT SUGGESTION UNDER HYPNOSIS

BY

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Many aspects of psychogenic deafness as encountered clinically in association with psychopathology have already been demonstrated in deafness produced in normal persons by direct suggestion under hypnosis (Erickson, 1938; Pattie, 1950). Such work to date has dealt only with deafness extending over the whole aural spectrum (total deafness). We have reported, in a preliminary communication, on the production of frequency selective deafness in this way (Black and Wigan, 1960), and we have now carried out further interpretation of our data and have performed a number of additional experiments.

Some of Erickson's subjects, in whom he produced various degrees of such total deafness by direct suggestion under hypnosis (D.S.U.H.), claimed to have subjective experiences of selective deafness, or were said to relieve anxiety by retention of the hearing of a single sound, such as the ticking of a clock. There was also objective evidence in some subjects of other sensory and even motor disturbance associated with this deafness: dilatation of the pupils, focusing disturbances, and nystagmus. One subject experienced concurrent general anaesthesia, with the greatest loss in arms and legs.

Pattie investigated unilateral total deafness produced by D.S.U.H. Earlier, Dynes (1932) experimented on the selective hearing produced by hypnosis *per se*, using the sound of a pistol-shot as the stimulus. Records were made of respiration, heart rate, and the psychogalvanic reflex (electrical resistance of the skin) both in the waking state and under hypnosis. Startle responses were reported to be absent under hypnosis, and no effect was observed on the heart rate or respiration. Slight changes of the electrical resistance of the skin were recorded. Total deafness can also be produced by post-hypnotic suggestion. This was investigated by Lundholm (1928), who showed that conditioned reflexes could not be established after such suggestions of deafness had been made and a sound tick was used as the conditioned stimulus and an electric shock as reinforcement.

Method

In our experiments records were made of the auditory thresholds of six deep-trance hypnotic subjects, first in the waking state and again after selective deafness to tones of specific frequency had been suggested under hypnosis. The evidence of deafness was then further investigated clinically and with the aid of positive conditioned reflexes, using an electric shock as the conditioning stimulus (reinforcement), tone as the conditioned stimulus, and heart rate as the conditioned response.

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