



Historical Review

The history of Guttman's and Whitteridge's discovery of autonomic dysreflexia

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Spinal Cord (2000) 38, 581–596

Keywords: autonomic dysreflexia

Introduction

Ludwig Guttman started treating spinal patients in 1944. He rapidly achieved recognition for his clinical management but it was his outstanding research work on autonomic dysreflexia, published in 1947, that established his scientific contribution. This work, more than 50 years later, is still acknowledged as being seminal.

In 1947 L Guttman and D Whitteridge¹ described how distension of viscera in a series of spinal patients had 'set up a response of autonomic mechanisms, which had induced profound effects on the cardiovascular activity in parts of the body above the level of the spinal lesion'.

The paroxysmal rise in blood pressure is recognised as being life threatening. These observations were not made in isolation but were part of a continuing series of studies on the sweating mechanisms and their control by the spinal cord initiated by Guttman when he worked in Germany.

I have found this application for a research grant by Guttman dated 21st November 1943 and 14th January 1944 to study sweating mechanisms in spinal cord injured patients at Stoke Mandeville Hospital which has not been published. It was overtaken by the definitive study with Whitteridge in 1947.¹

It reveals the evolution of Guttman's and Whitteridge's discoveries of the mechanism of autonomic dysreflexia and fills a gap in our understanding.

I worked with Guttman in 1956, published two papers with him on sweating in conjunction with C Wyndham in 1958² and W Randall in 1963,³ and other papers on the autonomic control of peripheral blood flow.^{4,5} Thus I am in a position to comment on the significance of the research application (see Appendix).

Discussion

Guttman's list of publications

Foerster, Guttman's chief in Germany, was interested in the control of sweating by the spinal cord. Guttman started publishing on the subject with List in 1928. He wrote about his sweat test in the seventh paper published in 1937 and described visceral distension causing sweating in 1938. By 1940 he was working on peripheral nerve injuries in Oxford. He was already an expert on the autonomic control of sweating and published a paper in 1941 on the Quinizarin method of studying sweating. He was known at Oxford as 'sweaty Guttman.' He did not carry out any studies at that stage on peripheral blood flow or blood pressure.

Despite being single-handed with a huge clinical burden of sick paraplegic patients in the terminal stages of toxæmia, he had applied for a very comprehensive research grant and three sessions to do research which is a mark of the man and the significance that he placed on research work.

Materials and methods

Guttman recognised the correlation between sweating and blood flow. He described how the Quinizarin method was used as an indicator of sweat gland activity and, for the thermo-regulatory sweat test, a special chamber was designed. Observations were made on the onset, amount and distribution of sweating in various parts of the body, techniques that I was trained to use at Stoke Mandeville Hospital.³

He studied the effects of distension of the bladder on sweating and vaso-motor function in conjunction with cystometrograms. The apparatus used for the cystometric studies was Riches' design of tidal drainage apparatus which was used when I was at Stoke Mandeville Hospital. In this study, no doubt he was trying to obtain changes by distending the

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bladder. For the body temperature test, a thermocouple apparatus was used.

There is no record of the need for blood pressure monitoring.

The clinical observation that prompted the study

Following a cystometrogram on 13.3.44 on a patient with a complete transverse lesion at T4, Guttman described in detail the effects of distension of the bladder which he took to be a mass response. There is no description of the blood pressure or pulse being studied so, in the first of the six patients, he did not recognise that blood pressure was being affected.

The same autonomic mass response was found in five other cases of complete spinal cord lesions and he promised more work would be published on the subject in due course. It was between January 1944 and March 1944 that the observations were made on the six patients.

The figure

Unfortunately the photographs of the patients are missing from Guttman's report but the figure survives. Although there is no record of blood pressure, there are meticulous and accurate observations in Guttman's own handwriting.

Fitting the jigsaw together

Viscero-cutaneous reflexes had already been recognised by Carmichael *et al*⁶ and Guttman,⁷ himself had written a paper on the subject in 1938.

When Guttman's application was made in 1944, he was not aware of the significance of the blood pressure. Whitteridge was assisting him in setting up the equipment, such as the thermocouples occasionally, but they were not working as a team. The crux of the study was the effects of bladder distension on sweating, vaso-motor function and skin temperature. He described sweating and headaches which he related to the bladder but there was no record of the blood pressure and he was proceeding to study the mechanism on the basis of blood flow and sweating alone.

It was during these studies that he fortuitously discovered that the blood pressure was raised. This served as the lynchpin of our understanding of autonomic dysreflexia.

Guttman recognised that sweating was only one manifestation of autonomic function and he pursued the blood flow control with Gilliat, who was a medical student, which was published in 1948.⁸ They were not aware of the overall cardiovascular changes since blood pressure was not recorded. There is no date but this work must have been carried out after March 1945 (when the last patient was injured) and before March 1947 when the paper was submitted.

Under the features that could interfere with the observations, they refer to contraction of the bladder causing autonomic disturbance and they refer to the Proceedings of the Royal Society of Medicine.⁹

In the Proceedings of the Royal Society of Medicine⁹ held on December 12 1946, Guttman described several patients with complete upper cord lesions, who, on distension of the bladder, developed patchy flushing of the face and neck, profuse localised sweating over the head and shoulders or at the level of the lesion, blockage of the nasal air passage and nasal voice, a slow pulse with occasional extrasystoles, respiratory discomfort and fullness in the head which progressed to severe occipital or frontal headaches. A research team was organised with Whitteridge and they found 'in such cases, the rise of blood pressure due to bladder distension was high and values of 190–260 mm.Hg of systolic and 125–135 mm.Hg of diastolic blood pressure were recorded.'

By 1946 Guttman realised that the rise in the blood pressure was the key to the problem and to investigate this, he arranged a collaborative study with Whitteridge which resulted in the paper that was published in 1947.¹

Guttman's relationship with Riddoch

On page 4 of his report Guttman talked about the 'mass response', which was a phrase coined by Head and Riddoch in the First World War to describe these phenomena.¹⁰ In the introduction to his paper with Whitteridge,¹ Guttman acknowledged the work by Head and Riddoch in 1917 but of particular interest is the letter from Guttman to the Secretary of the Medical Research Council dated 12 January 1945 which said 'Brigadier Riddoch, who was here at the end of last month, has already seen the details of my research, and he has asked me to publish them.' Riddoch was responsible for Neurology in the army and at Stoke Mandeville Hospital and this letter demonstrates that he was closely involved in Guttman's work. Guttman says that he is 'under the general supervision of Brigadier Riddoch' and states that he was doing three half-days per week research work.

Riddoch was a Neurologist to the Army and was Chairman of the Peripheral Nerve Injuries Units under which Spinal Units fell. He tried to organise a chain of spinal units throughout the UK. A unit at Stoke Mandeville Hospital should have been set up in 1940 but owing to local politics and the inability to provide adequate consultant cover, the unit did not open until 1944. At one stage Riddoch offered, on top of his other responsibilities, to be the visiting neurologist at Stoke Mandeville Hospital.

Guttman remained on affectionate terms with Riddoch. He acknowledged his debt to Riddoch, dedicated his textbook of spinal injuries to him, whom he regarded to be the father of spinal injuries.

Conclusion

This fascinating application reveals the evolution of Guttman's and Whitteridge's discoveries of autonomic dysreflexia, showing that the blood pressure effect was realised late on and demonstrates the close relationship which Guttman had with Riddoch, both in setting up the Spinal Unit and as his mentor in research work.

Acknowledgements

I would like to thank the Public Records Office for permission to publish this material, which was submitted when it was the Ministry of Pensions.

References

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- 2 Guttman L, Silver JR, Wyndham C. Thermoregulation in spinal man. *J Physiol* 1958; **142**: 416–418.
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- 5 Silver JR. Vascular reflexes in spinal shock. *Paraplegia* (1971); **8**: 231–242.
- 6 Carmichael EA, Doupe J, Harper AA, McSwiney BA. Vasomotor reflexes in man following duodenal distension. *J Physiol* 1939; **95**: 276–281.
- 7 Guttman L. Correlations between viscera and sweat glands in internal diseases (Viscero-sudoral reflex.) *Confina neurologica* 1938; **1**: 296–310.
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- 9 Guttman L, Whitteridge D. Section of Neurology. Discussion on the Treatment and Prognosis of Traumatic Paraplegia. *Proc R Soc Med* 1947; **40**: 219–232.
- 10 Head H, Riddoch G. The autonomic bladder, excessive sweating and some other reflex conditions in gross injuries of the spinal cord. *Brain* 1917; **40**: 188–263.

APPENDIX
Public Records Papers

PUBLIC RECORD OFFICE											6	7			
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MEDICAL RESEARCH COUNCIL

FORM OF APPLICATION FOR A RESEARCH GRANT

APPLICATION BY

....Ludwig Guttman, M.D. (Freiburg)

(N.B.- The applicant should complete this form after reading the information in the Council's pamphlet "Conditions attaching to Research Grants," and return it to the Secretary, Medical Research Council, c/o London School of Hygiene, Keppel Street, London, W.C.1.

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MEDICAL RESEARCH COUNCIL

FORM OF APPLICATION FOR A RESEARCH GRANT

N.B.—Sections A and B should be completed in every case, except that questions marked with an asterisk in Section A need not be answered by applicants already well known to the Council. One or more of Sections C, D, and E should be completed according to the nature of the grant sought.

A.—PERSONAL PARTICULARS

Full name	Guttman, Ludwig
Postal address	63, Lonsdale Road, Oxford.
*Date of birth	3rd July, 1899.
*Degrees, etc. <i>(with dates and sources)</i>	M.D. Freiburg, 1924. Dozent (Reader) of Neurology, University Breslau 1930.
*Present position	Research Assistant at the Nuffield Department of Surgery, University Oxford.
*Previous career	1924 Assistant, Med. Dept. Wenzel Hancke Krkhs 1925-1928 Assistant, Neur. & Neurosurg. Deptmt Wenzel Hancke Krankenhaus, Breslau. 1928-1929 Assist. Psych. Clinic, Univ. Hamburg 1929-1933 First Assist. Neurol. & Neurosurg. Departm. Wenzel Hancke Krkhs, Breslau Consulting Neurologist & Neurosurgeon at all Municipal Hospitals, Breslau. 1933-1939 Director Neurol. & Neurosurg. Deptmt of the Jewish Hospital Breslau Since 1939 (April, 1st) Present Position
*Principal scientific publications	Correlations between Sweating & Nervous Syst. (10 papers published between 1928 - 1941). Physiology and Pathology of the Cerebro-Spinal Fluid, Handbuch d. Neurologie, 1936, Vol. VII / 2 X-ray Diagnostic of the Central Nerv. System (Encephalogr., Myelogr., Ateriogr.) 1936 dto. Serobiolog. experim. on epileptics, 1928, Z.N. 112 Chronaxy & Actionpotentials in fatigue 1928 Factors affectg recovery of sensory function after nerve lesions, 1942, Journ. N. & Pach. V.
Complete list available if desired.	
*If desired, name of referee	

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B.—PARTICULARS OF THE INTENDED RESEARCH

Brief definition of the intended research <i>As a general rule a separate and more detailed statement of the scientific aims and methods of the proposed work should be appended</i>	Continuation of work on physiology and pathology of sweat glands* with special reference to spinal cord and spinal root lesions. √* and sensibility
Centre or centres where arrangements have been made for the proposed work	Spinal Cord Centre, Stoke Mandeville.
Name of director, if any, who has agreed to supervise the work <i>(Not applicable to senior workers)</i>	<i>Under the general supervision of Brigadier Geny Kiddoch.</i>
Probable duration of the proposed work	<i>One year with possibility of extension.</i>

C.—PARTICULARS REQUIRED FROM APPLICANTS FOR PERSONAL GRANTS

Amount sought <i>(In terms of rate per annum)</i>	<i>£200</i>
Whether for whole-time work, or, if not, for what proportion of time	<i>Three half days per week.</i>
Appointments, if any, to be held concurrently with the grant <i>(Give particulars of salaries and conditions)</i>	<i>(B1) Resident Officer at Spinal Cord Centre, Stoke Mandeville, Bucks. Salary at rate of £550 per annum if he lives out. His health & pension are willing to allow him the absence of or its equivalent for research work for which they agree he needs. he has extra to his salary.</i>
Whether applicant engages in private practice	<i>no.</i>

D.—PARTICULARS REQUIRED FROM APPLICANTS FOR EXPENSES GRANTS

Amount sought	<i>If for current expenditure in terms of rate per annum</i>	
	<i>If for non-recurrent expenditure as a single sum</i>	
Indication of the nature of the expenses <i>(e.g. Materials, laboratory or clerical assistance, etc.)</i>		

**E.—PARTICULARS REQUIRED FROM APPLICANTS FOR GRANTS TO
SCIENTIFIC ASSISTANTS**

(Grants for laboratory assistance are regarded as expenses grants)

Amount sought <i>(In terms of rate per annum)</i>	
Whether for whole-time work, or, if not, for what proportion of time	
Name of assistant with degrees, etc.	
Date of assistant's birth	
Assistant's present position	
Assistant's previous career	
Other work (including courses of study, etc.) to be undertaken by the assistant concur- rently with the grant <i>(Give particulars of salaries, conditions, etc.)</i>	

ANY ADDITIONAL REMARKS

*(Particulars of any other grant or payment expected or applied
for in respect of the proposed work should be entered here)*

It is understood that any significant change in the particulars given here that occurs
before the award or during the tenure of a grant will be notified to the Council.

Date 21st November 19 48

Signature of Applicant Henry Sulzberger M.D. (Frankfurt)

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Medical Research Council
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14th January, 1944

Application by
Dr. L. GUTTMANN, Oxford, for a part-time
personal grant at the rate of £200 per annum.

Dr. Guttman, who has the degree M.D. (Freiburg), is 44 years of age. He was formerly Reader in Neurology at the University of Breslau, and before coming to this country in 1939, he had held the appointments of Assistant in the Psychological Clinic, University of Hamburg (1928-29), First Assistant to the Neurological and Neuro-surgical Department, Wenzel Hancke Hospital, Breslau, and Consulting Neurologist and Neurosurgeon to the Municipal Hospitals, Breslau (1929-33), and Director of the Neurological and Neurosurgical Departments of the Jewish Hospital, Breslau (1933-39). Since then he has been Research Assistant in the Nuffield Department of Surgery at Oxford. He now seeks a part-time grant of £200 per annum to enable him to continue his work on the physiology and pathology of the sweat mechanism, with special reference to spinal cord and spinal root lesions. This work would be carried out at the Ministry of Pensions Spinal Cord Centre, Stoke Mandeville, where Dr. Guttman has been offered a post as Resident Officer (B₁) in the Emergency Medical Service, with salary of £550 per annum plus £100 per annum in lieu of board and lodging. Under the terms of the appointment, Dr. Guttman would be permitted to give the equivalent of three half days a week to the proposed research work.

The following outline of the investigation, which would be under the general supervision of Brigadier G. Riddoch, has been submitted by Dr. Guttman:-

"The suggested research represents the continuation of my work on the physiology and pathology of the sweat mechanism. The segregation of spinal cord and spinal root injuries in a Centre will enable a systematic study to be made on the correlation of the disturbance of sweating and sensibility during the various stages following injury.

The correlations of sweating and other functions such as heat regulation, mass reflex and oculo-pupillary function will also be studied. As indicator for the sweat gland activity the Quinizarin method will be employed since this has proved to be a most useful and simple method. This method will also be used for the clinical differentiation between pure spinal cord lesions and superimposed extraspinal lesions such as those of the sympathetic chain and ganglia, plexus and peripheral nerves."

Dr. Guttmann has published the following papers relevant to the proposed investigation:-

1. Zur Topik und Pathophysiologie der Schweißsekretion (Topography and pathophysiology of sweat secretion) 1928
Z.Neur., 116, 504-536. (In collaboration with C.F. List)
2. Die nervösen Leitungsbahnen der Schweißsekretion beim Menschen. (The nervous pathways of sweat secretion in man). Dtsch., Zeitschr. f. Nervenheilk., 1928, 107, 61-71.
3. Die Schweißsekretion des Menschen in ihren Beziehungen zum Nervensystem (The relations of sweat secretion to the nervous system in man). Z.Neur., 1931, 135, 1-48.
4. Epidemiologische, klinische und histopathologische Erfahrungen während der Poliomyelitisepidemie in 1932 in Schlesien (epidemiolog. clinic. and histopatholog. experiences during the Poliomyelitisepidemy 1932 in Silesia). Med. Klinik, 1933, 28.
5. Trauma und Wirbelsäule (Trauma and Spinal column). Hefte zur Unfallheilkunde, 1931, 8, 37-59.
6. Motorische und vegetative Grenzzonenreflexe bei Läsionen peripherer und zentraler Abschnitte des Nervensystems (Motor and vegetative borderzone-reflexes in lesions of peripheral and central parts of the nervous system). Z.Neur., 1933, 147, 291-307.
7. Ein neues einfaches kolorimetrisches Verfahren zur Untersuchung der Schweißdrüsenfunktion (A new and simple colorimetric method for the investigation of sweat glands activity). Kli. Wo., 1937, 35, 1212-1213.
8. Zur Frage der Wiederherstellung der Schweißdrüsenfunktion in Hauttransplantaten (Recovery of sweating in skin grafts). Dermatolog. Zeitschr., 1938, 77, 73-74.
9. Ueber reflektorische Beziehungen zwischen Viscera und Schweißdrüsen und ihre Bedeutung bei Erkrankungen innerer Organe (Der viscerosudorale Reflex). (Correlations between viscera and sweat glands in internal diseases (Viscero-sudoral Reflex). Confinia neurologica, 1938, 1, 296-310.
10. Lähmung des Nervus thoracicus longus mit Sympathicusschädigung als Sportverletzung (Paralysis of N.thorac.long. associated with sympathetic lesion following sport injury). Dtsch. Zeitschr. f. Nervenheilk. 1938, 145, 83-90.
11. Topographic studies of disturbance of sweat secretion after complete lesions of peripheral nerves. J. Neur. & Psych., 1940, 3, 197-210.
12. The distribution of disturbances of sweat secretion after extirpation of certain sympathetic ganglia in man. J. Anat. Lond. 1940, 74, 537-549.
13. Study on sweat secretion by the Quinizarin method. Roy. Soc. Med. 1942 Meeting of the Soc. of Physic. Med. November 4th, 1941.
14. Factors affecting recovery of sensory function after nerve lesions. J. Neur & Psych., 1942, 5, 117-129. (In collaboration with E. Guttmann).
15. The rate of regeneration of nerve. J. Exp. Biol., 1942, 19, 1. 14-44. (In collaboration with E. Guttmann, F.B. Medawar, J.Z. Young.
16. Extension of Nerve fibres in denervated areas. J. Neur. Psych., 1941, 4, 206. (In collaboration with G. Weddell and E. Guttmann)

DISTURBANCES OF SWEATING IN SPINAL INJURIES.

By Ludwig Guttmann, M.D.

M.O. i/c Spinal Injury Centre, E.M.S., Stoke Mandeville Hospital.

In this Report, some results of a study on the effects of injuries of the spinal cord and cauda equina on sweating are submitted. In this study, particular attention has been paid to the following aspects:-

- (1) Type and distribution of the sweating disturbances in lesions of the cauda equina and the thoracic and cervical portions of the spinal cord.
- (2) Correlations between the disturbances of sweating, sensibility and oculo-pupillary function.
- (3) The effect of bladder distension on sweating, vaso-motor function and body temperature.

Material and Methods.

Twenty five cases of spinal injuries were studied: thirteen were lesions of the cauda equina, twelve of various parts of the spinal cord. Nineteen cases were gunshot injuries, six closed fractures. The Quinizarin method was used, as indicator of sweat gland activity. All tests were carried out in a room set apart for the purpose, in order to provide standard conditions, especially for the sensory test after the sweating test. For the thermo-regulatory sweat test, in which sweating was induced by hot tea and radiant heat, a special chamber was designed. The chamber consists of a large wooden box, in which the patient can adopt a comfortable position throughout the test. The temperature within the box is regulated by eighteen 25 watt electric lamp bulbs, which are affixed well away from the patient's skin. The chamber is fitted with several glass windows to allow careful observation from all directions throughout the test. Two apertures on the top of the chamber allow photographs to be taken during the various stages of the test. During the test, observations are made on the onset, the amount and the distribution of sweating in various parts of the body. When the patient has adopted a suitable position in the chamber, the area of skin to be investigated is evenly dabbed with Quinizarin powder, and then the temperature within the chamber is raised gradually from room temperature to 120°F. The duration of heating required to produce adequate sweating varies from between 20 to 35 minutes. Care is always taken to produce maximum sweating. At the termination of the test, the temperature within the chamber is gradually reduced by extinguishing the lamps and opening the windows one after the other. After 10 or 15 minutes, when the patient has adapted himself to room temperature, the sensory examination is commenced. Touch sensibility is tested with a piece of cotton wool or one gm. v. Frey's hair, pain with a sharp needle, and temperature sensibility with two copper test tubes with a diameter of 3 cms., using temperatures of 40° and 115°.

The study on the effects of distension of the bladder on sweating and vaso-motor function was carried out in conjunction with cystometrograms. The apparatus used for the cystometrographic studies was Riches' design of tidal drainage apparatus, which is

provided

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provided with a manometer and thus allows continuous recording of detrusor action and pressure within the bladder during the test.

For the body temperature test, a thermo-couple apparatus is used, consisting of a set of six thermo-couples, connected with a spot galvanometer. This apparatus was set up by Dr. D. Whitteridge of the Department of Physiology of the University, Oxford, who also kindly assisted in the study of some of the cases.

Results.

Cauda equina lesions.

A comparison between figures 1 - 9 and 10 - 16 at once shows a distinction between two groups of cauda equina lesions - those uncomplicated and those complicated by superimposed lesions of peripheral nerves and sympathetic pathways. In the first group, (figures 1 - 9) sweating is, as one would expect, always present over the paralysed and anaesthetic areas. Moreover, as shown particularly in figures 4,5,6,7, and 9, it is even abnormally profuse in the distal parts of the lower limbs, and it commences very quickly in these areas after heating. In some cases, as shown in figure 6, there was marked spontaneous sweating without any application of heat. It is beyond the scope of this short report to discuss the question whether the increased sudo-motor function in this group of cauda equina lesions is a release phenomenon, due to interruption of sudo-inhibitory fibres, which are supposed to run in the posterior roots (Foerster, 1936), or whether this is due to direct irritation of sudo-motor centres or fibres in the lower thoracic and upper lumbar cord, caused by the pathological processes.

Of special interest are those cases of cauda equina lesions which are superimposed, either by lesions of peripheral nerves, such as external popliteal nerves due to pressure at the head of the fibula (figures 13,14,15, and 16 - see also Lewin, Lancet 1944), or by lesions of the sympathetic pathways, caused by the original injury (figures 10,11,12, and 14 - see also Guttmann 1931). Figure 10 demonstrates the extensive sudo-motor disturbance of the whole left lower limb in a case of crush fracture of the first lumbar vertebra in a coal-miner. Motor and sensory symptoms indicate a symmetrical conus-cauda equina lesion below T.12, L.1. The sweat test, however, clearly shows that the lesion is asymmetrical and superimposed by a lesion involving the sympathetic supply of the whole left lower limb. Figures 11 and 14 demonstrate complete bilateral cauda equina syndromes, due to gunshot injuries, below T.12 on the right and L.1, L.2 on the left side, and figure 12 shows complete unilateral cauda equina lesion on the left side below L.1. The three cases are characterised by lesions of sympathetic fibres derived from the upper lumbar ganglia. In addition, in the case demonstrated by figure 12, the sweat test also revealed a lesion of the left 9th thoracic nerve.

Thoracic Cord Lesions.

Figures 17,18 and 19 show disturbances of sweating in correlation to the disturbance of sensibility in complete lesions of the mid-thoracic portions (T.5,6 and 8) of the spinal cord, due to gunshot injuries. The uninterrupted line demonstrates the level of the anaesthesia, the interrupted (figures 17 and 18) or dotted

line

- 3 -

line (figure 19) demonstrates the level of the analgesic area. The sweat tests in these cases were carried out about 5 months (figures 18 and 19) and 18 months (figure 17) after injury, and the photographs were taken at the end of the test. The dissociation between loss of sensibility and loss of sweating is obvious in all three cases, confirming the view that the overlap in the distribution of the various segments of the spinal cord on sudo-motor function is different and larger than that on sensory function. It should be noted that, in the beginning of the test, there was a closer correspondence between sensory level and sweat level, and the level of the lesion was clearly defined by an earlier onset of sweating and a relative hyper-hidrosis of the dermatomes just above the level of the lesion. Further investigations of complete lesions of the thoracic cord on a greater scale may reveal interesting results in the still unsolved problem of the topographic relations of single spinal segments to sudo-motor function.

In the three cases described here, the question was also studied whether the eliciting of reflex responses by stroking and pin-prick stimuli on the soles would produce sweating in the anhidrotic areas below the level of the lesion, revealed in the thermo-regulatory sweat test. Although in all three cases flexion spasms of the legs were elicited, only in the case of figure 18 were a few patches of sweat seen in the distal third of the legs and dorsal aspect of the feet. These findings are in agreement with my former experience - gained in complete lesions of the spinal cord, due to compression by tumours - that there may be dissociation in response of the various components of the mass-reflex (Head and Riddoch, 1917).

Cervical Cord Lesions.

Figures 20 - 25 are sweat disturbances in incomplete lesions of the cervical cord. In the cases of figures 20/21 and 24/25, the lesions were caused by closed fractures - in the cases of figures 22 and 23, by gunshot injuries. The sweat tests were carried out about 5 to 12 months after injury. The clinical symptoms were of Brown-Séquard type. On account of the level of the lesions of the sudo-motor fibres in the cervical cord, the sweat disturbances in all cases include the face. However, a comparison between figures 20 and 21, and 24 and 25, which demonstrate the beginning and the end of the sweat test, shows that the pronounced difference in sweating of the face at the beginning of the test, had almost disappeared at the end.

The cases described here show two kinds of disturbances of sudo-motor function:-

(a) Unilateral disturbances (figures 21 and 22). In the case of figure 21, there is a marked hypo-hidrosis of the right side of the body, particularly marked distally from the mammilla region. In the case of figure 22, the hypo-hidrosis of the right side is only very slight at the end of the test.

(b) Segmental disturbances (figures 23, 24 and 25). In the case of figure 23, on the right side there was a hypo-hidrosis of the face, neck and clavicular region, whereas the hypo-hidrosis on the body involves the left arm and upper and middle part of the trunk. In the case of figure 25, the segmental character of the sweat disturbance

is

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is even more marked, as shown in the hypo-hidrosis of the right side of the trunk and the right leg below the knee. In all cases of cervical cord lesions, the sweat disturbance represents its own distribution and is dissociated from the disturbance of motor and sensory functions. This dissociation between sweat disturbance and pain and temperature sensibility is demonstrated in figures 21, 22 and 25. The interrupted line demonstrates loss of pain sensibility, the dots and crosses temperature sensibility.

Only in the case of figure 22 was the sudo-motor disturbance on the right side of the face associated with an incomplete Horner's syndrome. Dissociations between oculo-pupillary function and sudo-motor function in lesions of the cervical cord have been previously described. (Guttmann 1931, List & Peet 1939). In my own case, a revolver shot injury of the mid-cervical lesion, there was a nuclear paralysis of muscles supplied by left 5th and 6th cervical segments - especially deltoid and biceps - and a Brown-Séquard syndrome below that level. The pyramidal signs were, although bilateral, more marked on the left side. The sweat test showed almost complete anhidrosis of the lateral aspect of the upper arm and marked hypo-hidrosis of the left shoulder, upper chest, neck, and face. There was no Horner's syndrome and, in fact, the left palpebral fissure was slightly wider than the right. These findings have an interesting bearing on the question of the anatomical arrangement of the fibres and centres of the cervical and upper thoracic cord subserving sudo-motor and oculo-pupillary functions. The dissociation of the disturbance of these two systems indicates either a separate location or a different vulnerability of their fibres. At present, no definite conclusions can be drawn from the existing anatomical and experimental studies, and this problem requires further investigation.

Effects of bladder distension on sweating, vaso-motor function and skin temperature (supra-lesionary autonomic mass-response).

The instigator of this study was the following clinical observation.

On the occasion of a cystometrogram made on 13. 3.1944, in a case of complete transverse lesion due to gunshot injury at T.4 and sensory impairment also between T.1 - 3, the patient experienced a painful sensation in his bladder, spreading upwards to the mid-line of the trunk and throat and ending in both lateral aspects and the central part of the occipital protuberance region. At distension of the bladder with 160 ccs. fluid and elicited bladder contractions, he complained of a hot feeling in face and neck, and he developed patches of flushings in both lateral aspects of the face, ears, neck, and central part of the upper chest. This patchy vaso-dilatation over the chest involved the 3rd - 6th thoracic dermatomes. This localised vaso-dilatation was followed by an outburst of sweating in both axillae and upper chest, especially the central part including the 5th thoracic dermatomes at distension of about 200 ccs. There was no sweating and vaso-dilatation below T.6, although some flexion spasms of the legs occurred. These symptoms, including headaches, increased on further distension of the bladder, but disappeared gradually when the bladder was emptied by leakage through the suprapubic wound and micturition through the ureter. This mass response of autonomic vegetative activity above the level of a transverse spinal lesion, elicited by bladder contraction due to distension, was found regularly in repeated tests of this

case.

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case. The chart of the cystometrogram demonstrates the details of the test of 18. 3.1944. Since then, the same autonomic mass-response above the level of a transverse spinal lesion, although varying in intensity of the participation of the various components of this phenomenon, elicited by bladder distension, was found with surprising regularity in five other cases of complete spinal cord lesions. Four cases were transverse lesions of the upper thoracic cord, one was a transverse lesion of the cervical cord (incomplete at C.6, complete below C.8). In all these cases, skin temperature tests confirmed the rise of temperature above the level of the lesion and revealed, not only no rise of temperature in the paralysed lower limbs, but even showed a fall of temperature during the test. *in these cases*

The study of these phenomena is not yet completed, and further details will be reported in due course.

--ooOoo--

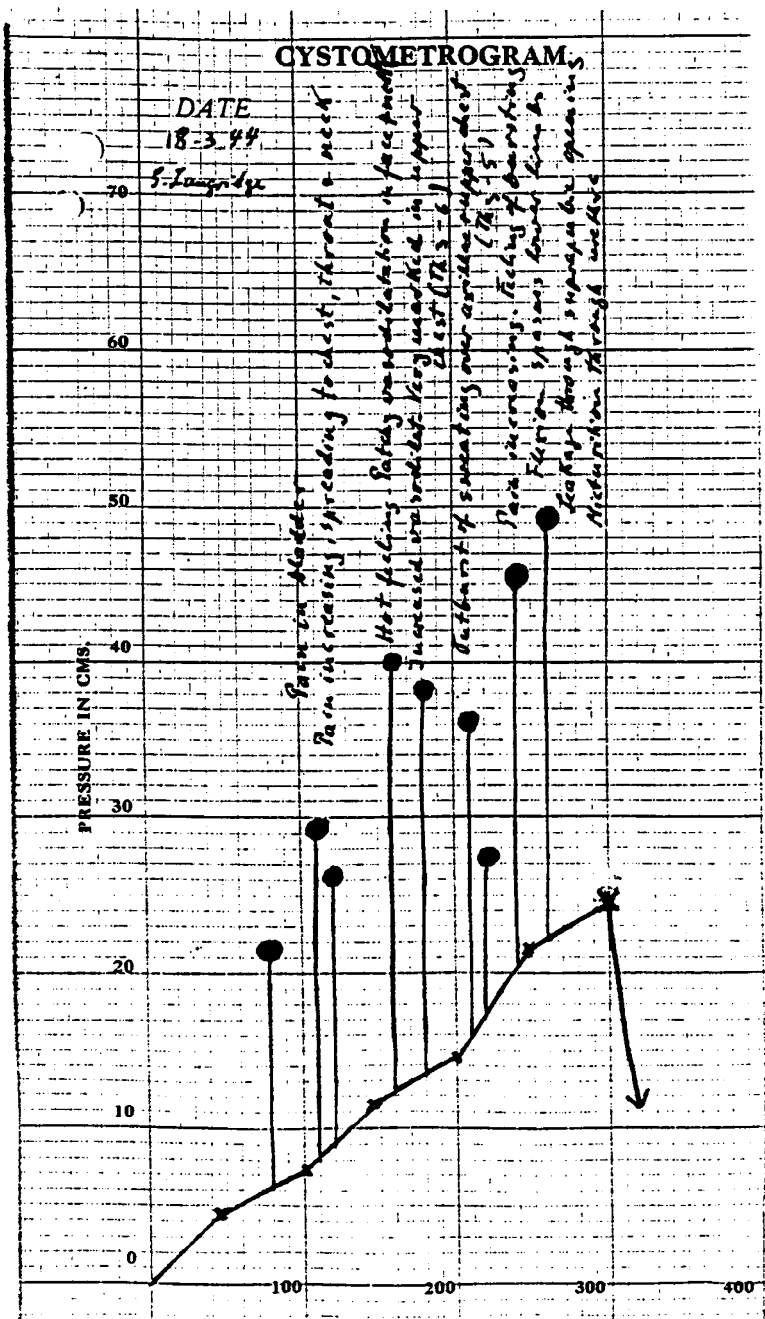
I wish to express my gratitude to the Medical Research Council and the Rockefeller Foundation for the grant which has enabled me to carry out this work.

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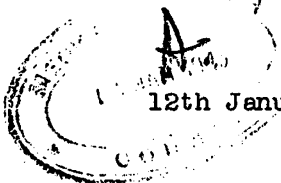
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LJS

SPINAL INJURY CENTRE,

Stoke Mandeville Hospital,
Mandeville Road,
Aylesbury,
Bucks.

Telephone:
Aylesbury 900.



12th January, 1945.

to A/c Riddoch

Dear Dr. Herrald,

I must apologise for the delay in submitting this report, but I have had some difficulty in getting my photographs ready in time.

I am enclosing the receipts for the apparatus purchased for the skin temperature test.

Brigadier Riddoch, who was here at the end of last month, has already seen the details of my research, and he has asked me to publish them. I shall certainly do so, with pleasure, when the study is completed. He also asked me to inform you that, at the moment, I am concerned with a research on healing of pressure sores in spinal injuries.

I take this opportunity to express my thanks to you for your kind interest in my work.

Yours sincerely,

Henry Putnam

Dr. F.J.C. Herrald,
Secretary,
Medical Research Council,
c/o London School of Hygiene,
Keppel Street,
London, W.C.1.

P.S. I should be glad if you would kindly return the photos when you have finished with them.