THE ANATOMICAL BASIS OF THE STRAUB PHENOMENON

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The administration of morphine was followed in white mice by a typical Straub reaction which consisted of the tail becoming rigid and erected across the back of the animal in an S-shaped curve. This reaction was accompanied by restlessness, excitability, extension rigidity of the hindlimbs, forcible voidance of faeces and prominence of the perineum. The Straub reaction was abolished by general anaesthesia with pentobarbitone or ether, by administration of tubocurarine, by bilateral section of the muscles causing extension to the tail, and by the removal of the circulation to the lower extremity. The reaction was modified by unilateral section of the extensor muscles of the tail. Section of the spinal cord, decortication, division of the anal sphincter and perineal floor, or ablation of the pelvic splanchnic nerves did not suppress the appearance of the Straub response. It was concluded that the phenomenon described by Straub (1911) was produced mainly by the action of the sacro-coccygeus dorsalis muscle, and that it was also necessary that the lumbo-sacral cord with its peripheral nervous outflow should be intact and that these functioning units should have an adequate circulation.

Straub (1911) described the sensitive biological reaction for morphine which bears his name. He stated that “when white mice are injected with a small quantity of morphine under the skin of the back, their tails go into a condition of catatonic rigidity which is manifested in such a way that, during the strongest dorsiflexion, the tail is in a position almost parallel to the vertebral column.” Subsequent investigators have confirmed and extended these observations. Herrmann (1912) called attention to restlessness, reflex excitability, extension paralysis of the hindquarters, lordosis of the vertebral column and an S-shaped curve of the tail. Van Leersum (1918) reported that defaecation occurred soon after the injection of morphine and that the perineum became prominent. The explanations for the phenomenon found in current textbooks of pharmacology show some disregard for anatomical and functional considerations, particularly in connexion with the skeletal and visceral musculature involved. Gad-dum (1955) states that “morphine has a peculiar effect on mice, making them hold their tails erect owing to spasm of the anal and vesical sphincters,” and similar explanations are given by Grollman (1958) and Sollman (1957). These explanations appear to stem from the work of Macht (1920), who confused skeletal with smooth muscle activity, and who credited Van Leersum (1918) with showing that “the stiffening of the tail was really due to spasm of the sphincters.” The present experiments were carried out in order to investigate the anatomical basis for the Straub and associated reactions which take place in white mice after the administration of morphine.

METHOD

Thirty-six healthy male and female white mice (T.O. Swiss Strain) of 25 to 30 g. body weight were divided into groups each of 3 animals. Operative procedures where necessary were carried out under sterile surgical conditions using ether anaesthesia. Prior to each observation, the mouse was injected subcutaneously with a solution of morphine hydrochloride at a dose equivalent to 100 mg./kg. of body weight. The observations were continued for a period of 1 hr. following each injection.

RESULTS

Group 1

No treatment and no surgical interference was given to these animals. A typical Straub reaction was always obtained (Fig. 1). Within 30 sec.
The appearance of a white mouse following an injection of morphine. The erection, curvature and disposition of the tail was described by Straub. Other prominent features shown here are the extension paralysis of the hindlimbs, lordosis of the vertebral column, and the prominence of the perineum.

Fig. 1.—The appearance of a white mouse following an injection of morphine.

of injection, the animal became restless; between 2 and 5 min., the tail stiffened and usually took up an S-shaped curvature, and the hindlimbs showed extension rigidity, the animal looking as if it were “stepping on tip-toe.” Faeces were voided, the anus protruded slightly, and the perineum became tense (Fig. 2).

Group 2

Before the injection of morphine, each animal was anaesthetized by an intraperitoneal injection of 32 mg./kg. of body weight of sodium pentobarbitone (Nembutal). No Straub reaction occurred under general anaesthesia. If the animal regained consciousness within 10 to 15 min. of the morphine injection, the phenomenon developed. If the period required for the return of consciousness was longer the response was not seen.

Group 3

These animals were anaesthetized with ether before the administration of morphine. No responses were observed while the animals were unconscious. However, a Straub phenomenon gradually appeared as consciousness returned. Conversely, animals exhibiting the Straub reaction lost the tail rigidity and other features of the phenomenon as soon as deep general anaesthesia was attained.

Fig. 2.—Tensing of perineum and voiding of faeces immediately following injection of morphine.

Fig. 3.—Bilateral cutting of the sacro-coccygeus dorsalis muscle has prevented the erection of the tail in the typical Straub reaction.
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FIG. 4.—After unilateral cutting of the sacro-coccygeus dorsalis muscle, administration of morphine was followed by a deviation of the tail to the side of the intact muscle.

Group 4
Following either subcutaneous or intramuscular injection of tubocurarine (0.0075 mg./animal), the Straub phenomenon could not be elicited. Treatment of an animal showing the Straub reaction with tubocurarine abolished the response.

Group 5
The extensor muscles and tendons to the tail on both sides were sectioned at their attachment to the vertebral column. The stiffening and S-shaped curving of the tail was abolished (Fig. 3), although the other features of the Straub reaction remained.

Group 6
The extensor muscles serving only one side of the tail were sectioned. Stiffening and curving of the tail occurred towards the side of the intact muscles (Fig. 4).

Group 7
The spinal cord was cut across at various levels at the lower thoracic and lumbar segments. Following morphine administration the animal became excited and a moderate stiffening and curling of the tail took place. The hindlimbs which were paralysed went into fuller extension than normal.

Group 8
Decortication did not prevent morphine causing the Straub reaction. The animals became markedly excited and an increased extensor rigidity occurred. Extension paralysis was more prominent than in the intact animal, and was followed by spasms and convulsions.

Group 9
The anal sphincter was divided by cuts along the long axis. Morphine administration was followed by a Straub reaction, but without forcible voidance of faeces or protrusion of the anus.

Group 10
The muscles associated with the perineal floor were cut on both sides of the pelvic outlet. Following morphine, a Straub reaction developed, but there was neither protrusion of the anus nor prominence of the perineum.

Group 11
The pelvic splanchnic nerves were destroyed by the clearance of fascia in the pelvic floor and posterior abdominal wall. When morphine was given, a Straub reaction associated with anal and perineal responses occurred.

Group 12
The abdominal aorta and inferior vena cava were ligated just above the bifurcation of the common iliac vessels. This produced immediate cyanosis of the tail and lower extremities, followed by local paralysis. The Straub reaction could not then be elicited.

FIG. 5.—Dissection to show the sacro-coccygeus dorsalis muscle which is responsible for elevation and rigidity of the tail. The pointer indicates the tendons leading from this muscle itself which appears as the darkened mass on each side of the vertebral column.
Fig. 6.—Tension on the tendons of the sacro-coccygeus dorsalis muscle has caused the tail to assume a position closely similar to that seen after morphine administration.

**DISCUSSION**

These experiments provide evidence that the phenomenon described classically by Straub (1911) is dependent upon two primary anatomical units. One neural, composed of segments of the lumbo-sacral cord, the lower motor neurone outflow and functioning motor end-plates. The other musculo-skeletal, consisting of intact musculature to the tail with tendinous attachments to a multi-articulated skeleton.

The muscle specifically responsible for the rigidity, dorsi-extension, and S-shaped curving of the tail was the sacro-coccygeus dorsalis muscle (Fig. 5). Contraction of this muscle gave rise to the typical appearance of the tail following morphine administration (Fig. 6).

Our experiments showed that the constriction of the anal and vesicle sphincters does not appear to be the cause of the Straub phenomenon. However, anal and perineal responses did occur after injection of morphine into white mice, but formed only part of a much wider pattern of muscular activity.

These findings are in agreement with those of Heinekamp (1923), who concluded that "the Straub biologic test is due to direct stimulation of the spinal cord." Furthermore, from electroencephalographic studies, Leimdorfer (1948) found evidence that the elevation of the tail was a reflex phenomenon originating in the spinal cord. He suggested that it was likely that morphine facilitated an increased activity along the cerebro-spinal pathways.

**REFERENCES**


