Neurophysiological basis for acupuncture

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Introduction

Acupuncture is defined as the insertion of needles through the skin at specific points for the purpose of treating various disorders by stimulating nerve impulses. Originally Chinese, this method of treatment is practised in many parts of the world. It is also known as stylostixis [Latin acus, *needle*; see ak- in Indo-European roots + puncture].

Whilst acupuncture has been in use for thousands of years in China and Asia, it has really only become widely known in the west since the 1970s at which point research into the scientific basis of acupuncture began (see White *et al.* 2008, for review of literature).

Acupuncture points and meridians

Acupuncture points: 361 different points are recognised in traditional Chinese medicine (TCM). There is no objective test for the points and their precise location varies between practitioners; some points are associated with lowered galvanic skin resistance, nerve endings or vascular bundles.

Meridians: From TCM, there are 12 primary meridians, which are thought to be energy channels that flow around the body; the majority have names of organs, e.g. liver, gall bladder, heart, although this does not mean the physical organ. Needling is thought to modulate the energy flow in TCM. The basis of meridians in western acupuncture is still under discussion; they may reflect fascial lines around the body, have relationships to trigger points, or just be a concept of Eastern medicine.

Needling

Acupuncture needles are fine, non-cutting, flexible, and commonly sized 0.25 x 30mm or 0.16 x 30mm. Larger diameter needles are also available. Commonly used needles are sterile, single use and made of stainless steel. In humans needling induces sensations of sharp pain, numbness, distension/fullness or radiating sensation, heaviness, warmth or dull ache like muscular fatigue. To increase the potency of the stimulation, needles may be manipulated (twirled, pistoned) or stimulated via an electrical current across paired needles (electroacupuncture). Contraindications for acupuncture include oedematous, infected or damaged tissue (skin, hypodermis, muscle, sepsis), needling into blood vessels, or body cavities, coagulopathies or a compromised immune system; caution is recommended if the patient is pregnant. Electroacupuncture should not be used near implanted electrical devices (e.g. cardiac pacemaker). Animals may be drowsy or exhibit some stiffness in the first 24 hours after a treatment. Fainting has been (rarely) recorded in humans during treatments. Treatments are usually several days to a week apart in the first instance and, if required may be used for maintenance therapy several weeks apart.

The neurophysiology behind acupuncture

There are five basic effects:
1. Local effects
2. Segmental effects

3. Heterosegmental effect
4. Central effects
5. Effects on myofascial trigger points (TrPs)

Local effects

Needling results in local erythema, +/- swelling (weal formation) by stimulating the local network of branching superficial sensory nerves (the axon reflex) resulting in local release of many vasoactive agents including histamine, calcitonin gene-related peptide (CGRP) and substance P. Release of CGRP from sensory nerve endings promotes both vasodilation and the growth of new blood vessels after injury, to facilitate healing. The vasodilation may cause stimulation of local glands; for example, saliva production after local needling. Release of nerve growth factor is also triggered. The local effects are utilised in the colourfully named 'Fencing the Dragon', in which a wound is surrounded by needles to stimulate blood flow. This technique results in improved wound healing and healing of skin flaps.

Acupuncture analgesia

Analgesia is one of the most common reasons for using acupuncture. Pain is defined as 'An unpleasant sensory and emotional experience associated with actual or potential tissue damage' (IASP: Int. Assoc. for the Study of Pain). It has both a sensory component (nature, quality and duration) mediated through the somatosensory cortex of the forebrain AND an affective component (how disturbing it is to the individual) – mediated through the limbic system. Noxious stimulation. 50% of nerve fibres in the peripheral nervous system (PNS) transmit nociceptive stimuli, involving two main nerve fibre types. i) A-δ fibres are myelinated and therefore fast-conducting fibres that project to the somatosensory cortex. They allow the individual to accurately localise the stimulus (e.g. animal scratching/biting at a biting insect), and elicit a response that withdraws the animal from the stimulus. ii) C-fibres are non-myelinated, slow-conducting fibres that are responsible for producing the dull, aching, throbbing types of sensation; they have an aversive effect (emotional/limbic system) and encourage the individual to withdraw and rest to allow healing to occur. Input from the PNS of the body (via spinal or cranial nerves) enters the spinal cord or brainstem, respectively where it may elicit a local protective reflex (e.g. withdrawal or palpebral reflex). Information that enters the spinal cord will also travel cranially in several different tracts to the brain (brainstem and contralateral forebrain). Similarly, nociceptive input from the head (via CNN V, VII, IX, X) enters the brainstem and is transmitted to the contralateral forebrain. Chronic noxious stimuli can lead to central sensitization, where both the PNS and the CNS become sensitised to the stimulus and, with time, the same level of stimulus results in increased perception of pain. This is due to increased receptor sensitivity, recruitment of additional neurons and activation of other neurotransmitters; thus the same level of stimulus is perceived as being more intense (hyperalgesia). Ultimately, with such recruitment (wind-up), then non-noxious stimuli can be perceived as being noxious (allodynia).

Segmental effects

Many sensory nerves feed into the dorsal horn of the spinal cord, including the A-δ fibres and the C-type fibres both from the body surface and viscera. Needling stimulates the A-δ fibres from the skin and type II/III fibres from muscle that, on arrival in the dorsal horn, cause activation of enkephalinergic inhibitory interneurons. These interneurons inhibit the incoming C-type fibres, in the tip (substantia gelatinosa) of the dorsal horn, from stimulating afferent fibres travelling to the brain; thus the transmission of noxious stimuli is reduced. The neurotransmitter, enkephalin causes generalised depression of dorsal horn activity, with an onset in minutes, and a duration that can last for days. This is the main pain-relieving mechanism of acupuncture. The effect will occur with stimulation of any part of the body that has input onto the dorsal horn. The inhibitory neurotransmitter, GABA (γ-amino butyric acid) may also be released, potentiating the inhibitory effect.

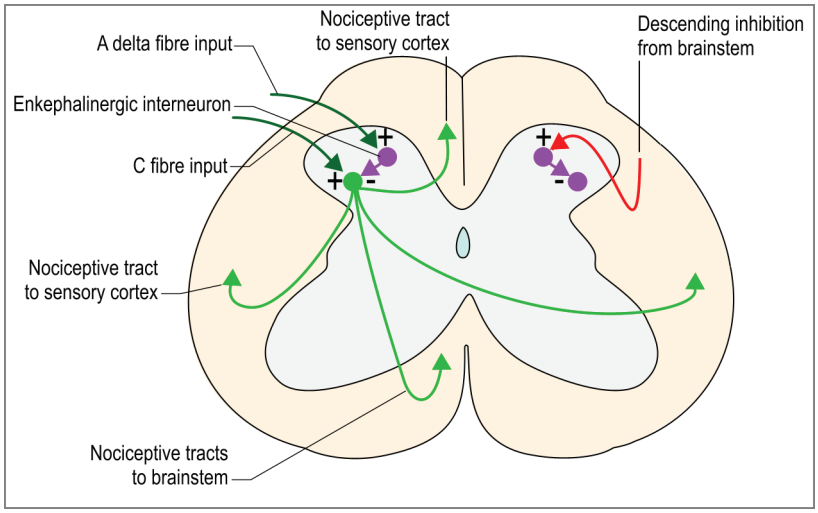

Figure 1. Segmental and heterosegmental mechanisms of acupuncture (modified from Thomson and Hahn, fig 6.5). Somatic afferent fibres are in green, interneurons are in violet, caudally-directed, inhibitory fibres are in red; these indicate the pathway used to activate the heterosegmental effect of acupuncture

Stimulating any afferent nerves connecting to the dorsal horn that is receiving the noxious stimulus can activate the segmental effect of analgesia. Thus it will be elicited by stimulating the dermatome/cutaneous zone (area of skin supplied by a spinal or named nerve of the PNS), or the muscles (myotome) or periosteum (sclerotome) innervated by that spinal cord segment. The same nerves that innervate muscles will innervate the associated joints. Thus treating the muscles acting on the joint will help decrease transmission of noxious stimuli from that joint. For example, the skin, muscles and fascia/ligaments around the stifle would be needled to treat osteoarthritis of the stifle. Dermatomes can extend over quite a large area, thus sites somewhat distant to a painful area may be stimulated and will still activate the appropriate dorsal horn. For example to treat elbow pain, 3-6 acupoints local to the joint would be used (stimulating sensory input from both the skin and muscles around the joint to spinal cord segments C7-T1), but distant points such as on the distal metacarpals (e.g. TH[1]-3 or SI-3) or on dorsal midline between the scapulae (BL-11) will stimulate the radial nerve cutaneous zone and C8 or T1 dermatome, respectively.

Analgesia from segmental acupuncture will be associated with relaxation of tense muscles, (improving joint mobility and blood flow and reducing myofascial trigger point activation – see later). The analgesic effects can last for several days, and repeated treatments will have a cumulative effect.

Visceral pain

Afferent/sensory fibres from viscera travel to the spinal cord and brainstem via the autonomic efferent pathways. They synapse in the dorsal horn of the spinal cord, in the same area as somatic afferents from the skin and musculoskeletal system. Because of this convergence of somatic (skin/muscle/periosteal) sensory neurons and visceral afferent neurons onto the same dorsal horn, the skin/body wall can be used to treat visceral pain; this will involve the segmental mechanism described previously. Thus to treat visceral conditions, it is important to know the segmental innervation of that organ. Input from the heart and lungs synapses in spinal cord segments of the cranial thoracic region (C8-T5/6); gastrointestinal tract afferents synapse from the midthoracic to the mid lumbar region; and pelvic visceral afferents synapse in mid lumbar and sacral segments. For example, the heart and lung are innervated by T1-T5 spinal cord segments. In TCM, heart and lung conditions are treated using points (BL 13-16) in the cranial thoracic area on the bladder meridian, which runs bilaterally, parallel to the dorsal spinous processes. These bladder acupoints correlate with the dermatomes supplied by the cranial thoracic spinal cord segments.

[1] TH, SI and BL refer to specific points on different meridians

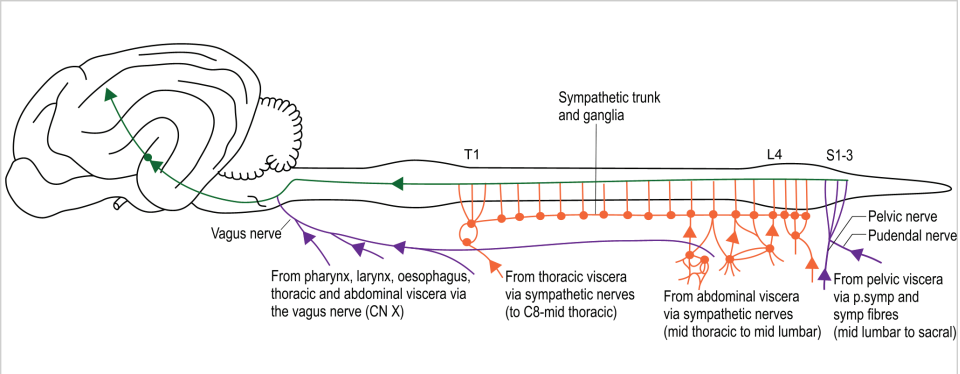

Figure 2. Visceral afferent fibres (adapted from Figure 6.7, Thomson and Hahn). Visceral afferent fibres travelling via parasympathetic pathways are in purple. Visceral afferent fibres travelling via sympathetic pathways are in orange

Treating the myofascial trigger points (TrPs) to treat visceral pain. Myofascial trigger points are areas of hypercontraction within a muscle – see later. These are often painful. They form because of viscerosomatic reflexes in which visceral stimulation results in changes in the musculoskeletal system (soma) (Figure 3). Noxious stimulation of the viscera (e.g. pancreatitis) can result the formation of painful TrPs in the abdominal wall. Thus insertion of acupuncture needles in body wall TrPs will stimulate the same dorsal horn as is being stimulated by the visceral afferents, and help to block nociceptive input from the viscera via the segemental mechanisms described above involving enkephalin and GABA. Needling the TrPs will also help deactivate them. For example, needling the dermatomes T12 and T13 (BL-21 to BL-23) and TrPs in the cranial abdominal wall muscles could help treat the pain of pancreatitis.

Treating visceral motor function by superficial needling. This co-opts the pathway for viscerovisceral reflexes in which visceral input triggers visceral efferent output modulating smooth muscle function within the organ and/or the smooth muscle in the blood vessel supplying the organ (Figure 3). Visceral motor activity is also controlled by the brain (hypothalamus). Acupuncture can affect visceral activity by affecting brain neural activity (see CNS effects later) and local reflex activity. In the latter, this is again due to convergence of both somatic afferent and visceral afferent in the same dorsal horn. Therefore, somatic (skin/body wall) stimulation can modulate processing of visceral afferent input such that visceral efferent activity is altered. For example, the point ST-36 in the belly of the cranial tibial muscle is innervated by sacral segments; so is the pelvic viscera. Thus needling this point, just distal to the stifle, can be used to treat pelvic visceral problems e.g. urinary bladder.

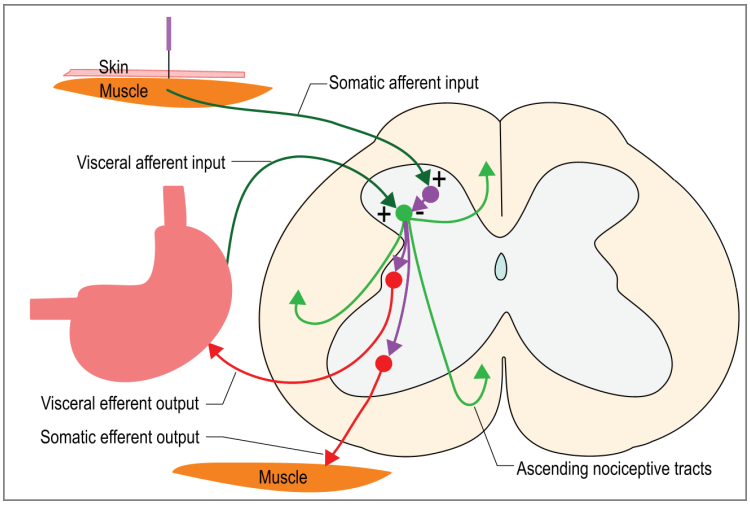

Figure 3. The wiring for somatvisceral and viscerosomatic reflexes and how acupuncture might influence both reflexes via the segmental effect

Heterosegmental effects

This involves indirect activation of many spinal cord segments other than the local one, via stimulation of the brain. It has both humeral and neural components and is used to reinforce segmental analgesia.

Needling stimulates peripheral nerves, the local spinal cord segment and then, via cranially directed pathways of the spinal cord, it stimulates the brainstem causing release of a variety of neurochemicals including opioids, oxytocin and serotonin. The most potent opioid is β-endorphin; detectable amounts are found in the CSF and also the vascular circulation after needling. Other opioids are also released especially after electroacupuncture. The effects of endogenous opioids are blocked by naloxone. Oxytocin has mild analgesic and sedative properties, as well as being an anxiolytic agent. Serotonin release in the brainstem stimulates caudally-directed pain inhibitory mechanisms resulting in suppression of noxious stimuli in the dorsal horns of many spinal cord segments (heterosegmental effect) utilising noradrenaline and the inhibitory enkephalineric interneurons (Figure 1). The heterosegmental effect is modest and causes generalised analgesia.

Needling points distant to the site of the problem and with innervation unrelated to that of the affected spinal cord segment, is done to activate the heterosegmental effect. For example, a stifle problem will be treated with local points, but may also involve acupuncture in the epaxial muscles at the level of T1 and L2 vertebrae (BL-11 and 23, respectively).

Central effects

Input to the forebrain from peripherally stimulated areas stimulates the brainstem and somatosensory cortex. It also stimulates the hypothalamus, where it may influence the autonomic nervous system; this is the location of the upper motor neuron control centre for the autonomic nervous system. It also stimulates the limbic system, which functions in emotion and memory, where it can induce a general calming/euphoric effect, sleep and an improved sense of wellbeing. Emotional responses have also occurred in people after treatment. Via effects in the limbic system, acupuncture may alter the affective component of pain. People report feeling calmer and more relaxed or sleeping well after acupuncture. Animals will often be drowsy and sleep more after treatment. Changes in limbic system activity have been seen on functional magnetic resonance imaging after needling single potent 'master' points (e.g. ST-36 in the cranial tibial muscle). Acupuncture may also effect activity in the vomiting centre of the brainstem, and hence be useful for treating nausea (PC-6, CV-2 or ST-36), although the precise mechanisms are unclear.

Effects on myofascial trigger points (TrPs)

Myofascial TrPs are hypercontracted areas in the muscle and are palpable as knots or taut bands. They are painful, either upon palpation or spontaneously so (latent versus active TrPs, respectively), or they can cause referred pain. Biomechanically, they shorten and weaken the muscle and can reduce the range of joint motion by 10-15%. They cause pain, stiffness, and restricted range of motion. They are not found in babies and tend to accumulate throughout life. Myofascial TrPs are thought to be responsible for much of the decrepitude of advancing age. They have been identified in a wide variety of species including horses, dogs, cats, rabbits, rats, humans and even in sharks.

Myofascial TrPs are caused by strain, trauma, lameness (which causes strain in supporting muscles) and pain. These factors result in sustained focal contraction within a muscle, which results in reduced perfusion of that area, an hypoxic environment and local energy crisis, causing release of inflammatory mediators such as cytokines (bradykinin, TNF-α, IL-β) and substance P that activate sensory nerve endings. Flexor muscles are particularly prone to the development of TrPs as there is sustained muscle contraction to withdraw and protect the painful area. Approximately 50% of people have TrPs in their trapezius muscles; these TrPs are often associated with the person having a forward head carriage (e.g. to peer at a computer screen) thus the trapezius muscle is under continual load trying to stabilize the head position. These trapezius TrPs are often painful, especially on palpation, and cause tension headaches (referred pain to the head).

Common sites for TrPs in dogs are the sublumbar muscles (iliopsoas and quadratus lumborum mm.) the sartorius, rectus femoris, semimembranosus and semitendinosus, adductor, gastrocnemius, triceps, latissimus dorsi, brachialis, infraspinatus and pectoral muscles.

Due to convergence of visceral and somatic fibres on the same dorsal horn, with reflex connections to motor nerves in the intermediate horn (autonomic nerve cell bodies) and ventral horn (somatic nerve cell bodies) (see figure 3), afferent input from TrPs can also cause autonomic dysfunction (somatovisceral reflex), while visceral pain can cause the formation of TrPs in body wall muscles (viscerosomatic reflex).

Clinically, TrPs can result in pain behaviour, altered posture (abduction, adduction, pelvic tilt, kyphosis) and gait, restricted movement, and in humans are known to cause referred pain. Myofascial TrPs do not respond to treatment with NSAIDs, muscle relaxants or steroids, although such drugs may treat the referred pain. They can be treated effectively by massage, focal and sustained pressure (30-60 seconds), transcutaneous electrical stimulation (TENS), all followed by passive stretching of the muscle. Needling straight into the TrP is an effective way of treating the TrP both to decrease the pain from them (direct and referred) and to increase muscle function.

Myofascial TrPs are found in predictable sites throughout the body and there is significant overlap between these sites and the location of acupuncture points. There are 255 common TrPs in the human body and many of these are close to acupuncture points giving rise to the hypothesis that many acupoints may be TrPs.

Summary

Acupuncture has five main effects: local for wound healing ('fencing the dragon'), segmental (most potent effect), heterosegmental (generalised analgesia), central (calming, sedative) and trigger point relief. It may cause analgesia from somatic and visceral tissues, and affect the contractility in both striated and smooth muscle.

Further reading

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