Introduction

Hiccup is a widely experienced and less understood phenomenon. Although much is known about the afferent and efferent limbs of the hiccup reflex pathway, no definitive consensus exists on the hiccup centre generating this reflex. Even the word “hiccup” is an onomatopoeic for the sound the reflex arc produces [1].

The hiccup reflex arc can be categorised as having afferent and efferent limbs and a central connection. The afferent limb is composed of the vagus and phrenic nerves, and the lower sympathetic (T6–12) segments. The efferent pathway is constituted by the phrenic nerve (C3–5) innervating the diaphragm, plexal branches to the scalene muscles (C5–7), recurrent laryngeal nerve to the glottis and the intercostal nerves (T1–11) innervating the intercostal muscles [2,3]. The hiccup central connection is believed to be spinal cord segments rostral to medulla oblongata (C3–5) in the reticular formation in the middle and dorsolateral segment, connecting to the hiccup rhythm centre in the Pre-Botzinger complex, nucleus ambiguous, lateral reticular nucleus, hypothalamus and mesial temporal lobes [2–5]. Gama-Aminobutyric Acid (GABA) and dopamine act as neurotransmitters for this reflex.

It is speculated that the hiccup centre and the respiratory centre although separate may interact with one another through the various neuronal connections [2,5].

When the hiccup reflex is triggered there is synchronous contraction of the inspiratory thoracic muscles and the diaphragm. This is followed, in 35 milliseconds, by an abrupt glottal closure producing the typical “hic” [6].

There is no conclusive knowledge on how this reflex is triggered but a safe idea would be that any mechanism which irritates or damages the components of the reflex arc, the central nuclei, the vagus, phrenic or other nerves of the autonomic system can trigger a hiccup. Of these the vagus is particularly important. The “wanderer” has such immense distribution throughout the body that the reflex can be triggered by any number of odd reasons such as irritation of the ear drum, rapid change in body temperature, over distension of stomach, irritation of the respiratory tract stroking of hair [7,8]. As such most initial remedies seem to centre on over stimulating the vagus nerve [9,10]. In cases of known underlying pathology treatment of the causative factor may help relieve the symptoms [11]. Table 1 enlists the various causes of a hiccup. Gastro-oesophageal Reflux Disease (GERD) has been shown to be both...
Table 1: Possible Causes of Hiccups adapted from Steger et al.

| Central/Peripheral Nervous System | Gastrointestinal | Thoracic | Ear, Nose & Throat(ENT) | Metabolic | Pharmacologic/Toxic | Surgical | Psychosomatic |
|----------------------------------|------------------|----------|-------------------------|----------|---------------------|----------|---------------|
| Ischemic/haemorrhagic stroke      | Gastric Distension | Cardiac Ischemic Injury | Infection | Hypo/Hyper-Glycaemia | Alcohol | Thoracic Surgery | Anxiety |
| Tumours                          | Gastro-oesophageal Reflux Disease | Cardiac Infection | Inflammation | Hypo/Hyper-Natremia | Chemotherapy/Radiotherapy | Abdominal Surgery | Stress |
| Traumatic Brain Injury           | Hiatus Hernia     | Cardiac Inflammation | Foreign Body | Hypo/Hyper-Kalemia | Steroids | Ear, nose, throat Surgery | Excitement |
| Infection                        | Gastrointestinal tumours | Pulmonary Inflammation | Tumours | Hypo/Hyper-Calcemia | Inhalational Oxygen | Endoscopy | Fear |
| Inflammation                     | Infection         | Pulmonary Inflammation | Tumours | Hypocapnemia | Benzodiazepines | Pharyngeal Intubation |
| Demyelinating diseases           | Inflammation      | Thoracic Tumours | Hypo/Hyper-Uraemia | Dopamine Agonists | Placement of Central Venous Catheter |
| Auto-immune diseases             | Obstruction       | Aneurysms | Metabolic Diseases | Opioids | Iatrogenic Injury |
| Neuro-transmitter abnormalities   | Haemorrhage       | Auto-immune diseases | Hypo/Hyper-Thermia | Barbiturates |
| Vascular abnormalities           |                   |            |                         |              |
| Anatomical Abnormalities         |                   |            |                         |              |

a cause of as well as a consequence of hiccups [1]. Although GERD can induce hiccups via the irritation of the vagus nerve, long standing hiccups in themselves can cause reduction in the oesophageal motility as well as lowering of oesophageal-gastric sphincter pressure thus favouring GERD [1,6].

Hiccups are classified as temporary (<48 hours), persistent (48 hours–1 month) or intractable (>1 month), depending on their duration [3]. Intractable hiccups may cause debilitating problems such as insomnia, anorexia, fatigue, exhaustion, weight loss, depression, opening of surgical wounds, development of hernia and haemorrhoids, inability to undergo imaging such as MRI and even death. In such cases active management is required. Numerous medical and alternative therapies are available for the treatment of hiccups. Rarely surgical interventions are employed [2,8,12]. Tables 2,3 provides an overview of the different treatment modalities for hiccups.

**Case report**

An 85 year old gentleman with a 9 year history of intractable hiccups came to us after numerous unsuccessful traditional medical and alternative treatments.

His symptoms started in 2010 when he suffered from pneumonia which caused severe respiratory compromise and fever. Prompt hospitalization and medical management attained full recovery, however a few days later the patient developed hiccups. Patient had a past medical history of ischaemic heart disease of 10 years, hypertension and hypercholesterolemia, both of which were very well controlled with amlodipine and rosuvastatin, and had no symptoms of hiccups prior to the pneumonia in 2010. Patient neither consumed alcohol nor smoked and did not indulge in recreational drugs. Initially the hiccups were for intermittent onset, about 2–3 per day with months of remission between successive episode. Gradually they became more consistent, occurring daily with a frequency of about 50–100 per day. Patient was still able to carry out his daily routine and used home remedies such as drinking cold water, re-breathing in a paper bag, pressure over eye balls, Valsalva manoeuvre and splashing cold water on face to treat his hiccups.

However the hiccups progressively worsened in frequency, rate, intensity and magnitude. In 2013 patient developed GERD, possibly as a consequence of the ongoing hiccups and underwent Nissen fundoplication. Fundoplication completely resolved GERD but the hiccups continued to worsen. 3 years ago they became non-stop occurring every 5 seconds and continued during sleep. They were symptomatic and disabling and scored 9/10 on a 10-point subjective patient scale. They caused severe distress to the patient who became progressively anorexic, irritated, short tempered, fatigued and depressed. He became emaciated over the years and found it hard to talk. Even normal breathing was upset with sensations of choking secondary to glottis spasms. Patient underwent countless medical evaluations; physical and neurological examinations including ENT, chest and abdomen; laboratory investigations including blood urea nitrogen; imagining including Magnetic Resonance Imaging (MRI) of brain and neck, Computed Tomography (CT) of abdomen and thorax and even upper gastrointestinal endoscopy and bronchoscopy. All examinations and investigations yielded normal results. In the absence of a definitive underlying cause an aggressive pharmaco-medical treatment was started. These medical therapies including prochlorperazine, metoclopramide, levitiracetam, baclofen, chlorpromazine, omeprazole, domperidone, gabapentin, carbamazepine, lansoprazole and Maalox plus remained ineffective. Patient also tried acupuncture, massage and hypnosis but to no avail. In 2018 the patient underwent left phrenic nerve blocking which provided temporary relief for half a day. Following this, the patient underwent left phrenic nerve resection which cured the hiccups for only 2 days.

Patient became progressively unwell and lost half of his body weight. Furthermore, the disquieting symptoms were temporarily relieved for approximately 30 mins only by the
induction of vomiting. Patient induced vomiting about 15 times in a day to experience relief from the hiccups.

In 2020 the patient was referred to our neurosurgery department for evaluation. All physical and neurological examinations, relevant imaging and blood investigations were normal. No underlying cause was ascertained. VNS is currently not approved for the indication of intractable hiccups, but given the fact that the patient had failed multiple lines of treatment and was disconsolate, after meticulous consideration and careful review of literature a decision was made for VNS insertion as a compassionate indication. Livanova VNS electrode was wrapped around the left vagus nerve of the patient and a pulse generator was implanted on the left chest above the pectoralis muscle 2-3cm below the collar bone. The surgery and post-operative period was uneventful. After 2 weeks of rest, the device was switched on with automatic current settings of amplitude between 1-2mA, frequency between 10-30hertz, pulse width between 500-1000 microseconds and duration of between 20-60 seconds. Pharmaco-medical treatment for the hiccups was discontinued. There was no hoarseness or change in voice of the patient and no chest pain or any sign of cardiac compromise.

This provided complete remission for few hours after which the hiccups returned but were infrequent with episodes lasting for up to 15 minutes, with a rate of 1 hiccup per second, every 4-6 hours, thus demonstrating a much decreased rate and magnitude. Patient and his family noted the intensity to be 5/10 on a subjective scale with marked improvement in speech. Due to the coronavirus (Covid-19) outbreak the patient is currently awaiting a follow up appointment to review prognosis and revise the automatic current settings.

We therefore document partial success with the surgical placement of vagus nerve stimulator for the treatment of intractable hiccups at our centre with short term results. As seen with epilepsy, VNS tends to continue to improve prognosis up to 1 to 1.5 years. We will continue to monitor the patient and present a follow up report with long term results.

### Table 2: Various Treatments of Hiccups adapted from steger et al.

| Vagal Stimulation                  | Respiratory Maneuvers                          | Centrally Acting Pharmacological | Peripherally Acting Pharmacological | Surgical                      | Alternative Treatment   |
|------------------------------------|------------------------------------------------|---------------------------------|------------------------------------|-------------------------------|-------------------------|
| Intra-Nasal application of Vinegar | Valsalva Maneuver                               | Chlorpromazine                  | Metoclopramide                     | Phrenic Nerve Blockage or Crushing | Hypnosis               |
| Inhalation of Smelling Salts/     | Breath Holding (Inspiration, Expiration)       | Phenotin                        | Domperidone                        | Phrenic Nerve Pacing          | Acupuncture             |
| Strong Odours                      |                                                |                                 |                                    |                               |                         |
| Swallowing Ice Water               | Re-Breathing (Hyper-capnia)                     | Haloperidol                     | Nifedipine                         | Percutaneous Phrenic Nerve Stimulation | Massage               |
| Splashing Cold water Or Cold      |                                                |                                 |                                    |                               |                         |
| Compress On Face                   |                                                |                                 |                                    |                               |                         |
| Induce Vomiting                    |                                                |                                 |                                    |                               |                         |
| Induce Fright                      |                                                |                                 |                                    |                               |                         |
| Carotid Massage                    |                                                |                                 |                                    |                               |                         |
| Pressure Over Eyeball              |                                                |                                 |                                    |                               |                         |
| Digital Rectal Massage             |                                                |                                 |                                    |                               |                         |
| Induce Orgasm                      |                                                |                                 |                                    |                               |                         |

### Table 3: Functional components of the vagus Nerve.

| 20% Efferent | 80% Afferent | Special Visceral Efferent |
|--------------|--------------|---------------------------|
| General Visceral Efferent (Pre- Ganglionic Parasympathetic) | General Somatic Afferent | General Visceral Afferent |
| Dorsal Motor Nucleus | Nucleus Accumbens | Motor Innervation | Reflexes | Sensory | Sensory | Receptors | Reflexes | Sensory |
| Thoracic Organs | Cardio-inhibitory Function | Soft Palate | Gag Reflex | Pharynx | Abdominal Organs | Aortic Arch Baroreceptors | Reflex Regulation of Gastrointestinal Tract | Epiglottis |
| Abdominal Organs | Pharynx | Cough Reflex | Larynx | Thoracic Organs | Carotid Sinus Baroreceptors | Reflex Regulation of Cardiovascular System | Taste Buds |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| Upper Part of Oesophagus | Trachea | Bronchi | External Auditory Meatus | Tympanic Membrane | Concha |
Discussion

Although temporary hiccups are a benign occurrence having no significant impact on the life of a person but intractable hiccups are a serious and debilitating pathology and often lead to dire consequences [1-3,7]. The world record of longest hiccups is 69 years with notable people such as Pope Pius XII dying from the ailment [13]. Therefore symptomatic intractable hiccups warrant medical and surgical treatment [1].

The vagus nerve forms a significant component of the hiccup reflex arc and can explain several odd triggers as well as the basis for most initial remedies [4,9,10]. In fact hiccups most frequently occur during inspiration when lung inflation impedes vagal afferents known to suppress hiccups [6]. The vagus nerve, also referred to as the “wandering” nerve or the “vagabond” nerve, greatly innervates multiple organs of the body and forms a part of several bodily reflexes [4,7,10]. Its stimulation has demonstrated varied functional outcomes the exact mechanism of most of which are not clearly understood [7]. VNS is an acknowledged treatment for epilepsy and depression [2].

Medical therapy for intractable hiccups comprises of GABA-derivatives, baclofen, dopaminergic antagonists and anticonvulsants. Non-traditional treatments such as acupuncture, massages and hypnosis are also widely used. Non-pharmacological options such as phrenic nerve blocking, crushing and pacing, percutaneous phrenic nerve stimulation and cervical epidural block have shown limited success due to the occasional presence of an accessory phrenic nerve as well as the bilateral diaphragmatic contraction aetiology of centrally originated hiccups [2,3,7,13].

Recently surgical placement of vagus nerve stimulators have been undertaken for chronic hiccups with varying degrees of success [2,5,7,10]. We report a case of intractable hiccups secondary to pneumonia, treated with VNS placement at our centre with short term results demonstrating partial success. Since the thorax is of immense anatomical importance in the hiccup reflex, it is reasonable to consider that infections of the chest can lead to hiccups [1]. Seeing as no validated questionnaires have been formulated to document the intensity of hiccups [1], a 10-point patient subjective scale was employed.

Very little research is available on the cure of hiccups and even the pathogenesis of hiccups is less understood. Due to the lack of a physiological relevance in adults and the observation of hiccups in foetuses along with the efficacy of baclofen in arresting gill-ventilation in tadpoles, it is speculated that hiccup is a phylogenetical reflex [2,4,6,13]. Future research will help us better understand this phenomenon and its treatment.

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