Functional Magnetic Stimulation Facilitates Gastric Emptying

Vernon W.-H. Lin, MD, PhD, Kathie H. Kim, MPH, RD, Ian Hsiao, PhD, William Brown, MD

ABSTRACT. Lin VW-H, Kim KH, Hsiao I, Brown W. Functional magnetic stimulation facilitates gastric emptying. Arch Phys Med Rehabil 2002;83:806-10.

Objective: To evaluate the effect of functional magnetic stimulation (FMS) on gastric emptying in able-bodied and spinal cord injury (SCI) subjects.

Design: A prospective, nonrandomized clinical experiment.

Setting: SCI and disorder center in a Veterans Affairs medical facility.

Participants: Five healthy, able-bodied subjects and 4 subjects with SCI.

Intervention: A commercially available magnetic stimulator was used; a round magnetic coil was placed along the T9 spinous process. The intensity of the magnetic stimulation was 60%, with a frequency of 20Hz, and a burst length of 2 seconds for the gastric emptying protocol.

Man Outcome Measures: Rate of gastric emptying and time required to reach gastric emptying half-time ($GE_{t1/2}$) with and without FMS. Data fit into linear regression curve.

Results: Accelerated gastric emptying was achieved in both able-bodied and SCI subjects. The mean ± standard error of mean of the $GE_{t1/2}$ at baseline and with FMS was 36±2.9 minutes and 33±3.1 minutes, respectively, for able-bodied subjects, and 84±11.1 minutes and 59±12.7 minutes, respectively, for SCI subjects.

Conclusion: Gastric emptying was enhanced by FMS in able-bodied subjects and was greatly enhanced in SCI subjects. FMS can be a useful noninvasive therapeutic tool to facilitate gastric emptying in humans.

Key Words: Gastric emptying; Magnetic stimulation; Rehabilitation; Spinal cord injuries.

CHRONIC GASTROINTESTINAL (GI) problems are common in patients with spinal cord injury (SCI). These chronic symptoms may be significant enough to alter lifestyle and require chronic treatment or even hospitalization.[1] Delayed gastric emptying has been described in a variety of neuromuscular dysfunctions including SCI.[2-6] Gastric emptying delay has been shown to impair drug absorption, causing therapeutic failure or toxicity in both able-bodied and SCI subjects,[3,7] In SCI, the connection between the thoracolumbar sympathetic outflow and the central control is disrupted, whereas the vagus pathway is preserved. This can lead to an imbalance between the parasympathetic and sympathetic outflow from the spinal cord to the GI tract, causing a dysmotility of the upper GI tract.[6]

Electric stimulation of the stomach has been tried by many investigators over several decades with mixed results. Electric stimulation helps create a consistent and coordinated train of waves that results in propagation of gastric pacesetter potentials of the stomach.[8-11] After implanting electrodes on the serosal surface and stimulating at a rate above the normal slow wave rate, significant improvement in gastric emptying was observed in patients with medication-resistant gastroparesis.[8] Despite recent advances, no electric stimulation protocol has been shown to reduce symptoms in a controlled fashion or to improve the well-being of patients with gastric motor disturbances.[12]

Functional magnetic stimulation (FMS) has been used effectively to stimulate the spinal nerves below the level of SCI, resulting in restored vital functions such as the ability to cough,[13,14] to empty the bladder,[15] to improve colonic transit,[16] and to produce lower-limb muscle contractions, which also enhances fibrinolytic activity.[17] In a recent animal study,[18] we further investigated the effectiveness of FMS to facilitate GI transits using orogastric gavage with a technetium Tc 99m sulfur colloid[a] (Tc 99m). FMS was performed over the anterior cervical and/or dorsal thoracolumbar regions using a figure of 8 coil. FMS accelerated gastric emptying and decreased GI transit time. The acceleration was dependent on the stimulation parameters used as well as on the duration of the protocol; high levels of FMS produced a quicker effect, whereas lower levels were effective at later times.[18]

Magnetic stimulation is noninvasive and not painful. Unlike electric stimulation, which requires direct contact with the tissue to be stimulated, magnetic stimulation can stimulate deep nervous tissue while the coil is placed outside of the body. Based on our earlier work in FMS of the GI tract,[16] we formulated this present protocol. The purpose of this investigation was to evaluate the effects of FMS on gastric emptying of solid meals in able-bodied and SCI subjects. A baseline gastric emptying study was performed followed by an FMS–gastric emptying study, which allowed for the detection of any improvements of gastric emptying with stimulation.

METHODS

Participants were recruited from the Long Beach Veterans Healthcare System, Long Beach, CA. Human subject consent forms and protocols were approved by the local institutional review board.

Five healthy, able-bodied subjects and 4 patients with SCI participated in this study. Each subject participated in a 3-day protocol. On the first day of the protocol, subjects received a baseline gastric emptying study. On day 2, there was no change in the eating pattern of the subject, and the subject did not have any intervention. By allowing the subject to rest on day 2, clearance of all Tc 99m was ensured because the half-life of Tc 99m is 6 hours. On day 3, subjects received FMS while undergoing a second gastric emptying study.

From the Functional Magnetic Stimulation Laboratory, Spinal Cord Injury/Disorder Health Care Group (Lin, Hsiao) and Nuclear Medicine (Brown), VA Long Beach Health Care System, Long Beach, CA; Department of Physical Medicine and Rehabilitation, University of California, Irvine, CA (Lin, Hsiao); and Clinical Research Department, Scripps Clinic, San Diego, CA (Kim).

Accepted July 16, 2001.

Supported by the VA Rehabilitation Research and Development.

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit upon the author(s) or upon any organization with which the author(s) is/are associated.

Reprint requests to Vernon W.-H. Lin, MD, PhD, Spinal Cord Injury/Disorder Health Care Group (07/128), 5901 E Seventh St, Long Beach, CA 90822, e-mail: *vernon.lin@med.va.gov*.

0003-9993/02/8306-6812$35.00/0

doi:10.1053/apmr.2002.32644

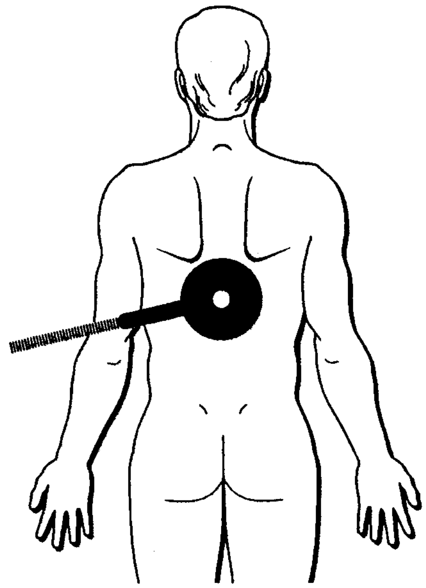

Fig 1. Human subject lying supine with a 12.5-cm, round magnetic coil placed at T9 of the spinal processes.

Gastric Emptying Study

All subjects fasted overnight for 12 hours. Two raw eggs mixed with 1mCi of Tc 99m were fried on a Teflon® pan without any added oils. Salt and pepper were added for taste. The fried egg was then placed on 2 pieces of toast and served with 112mL of water. This meal consisted of 314kcal, 21% protein, 34% carbohydrates, and 45% fat.

All subjects consumed the mixed meal sitting upright and finished the meal within 5 minutes. Then the subject was placed in a supine position. A gamma camera[b] was positioned over the abdomen, and radionucleotide imaging began. The test was conducted for a duration of 120 minutes with serial frame images taken every minute. The rate of gastric emptying was expressed as the time required to reach 50% of the initial count ($GE_{t1/2}$).[19] A region of interest was outlined at the end of 120 minutes to determine the $GE_{t1/2}$ counts in the stomach, and a correction was made for background scatter and radioactive decay. An additional calculation was performed in which each image taken at 15-minute intervals over a period of 120 minutes had a region of interest outlined. A correction was made for background scatter and radioactive decay. The data was fit into a linear regression curve.

FMS Protocol

In this 3-day study, days 1 and 2 did not require FMS. On day 3, magnetic stimulation was applied in conjunction with the gastric emptying study. A Dantec MagPro magnetic stimulator with a 12.5-cm coil[c] was used. The parameters were set at 60% intensity, 20Hz, with a 2-second burst length, and 28-second burst interval. Thirty minutes of stimulation (10min on, 5min off, 10min on, 5min off, 10min on) was given over the first 40 minutes of the 2-hour gastric emptying protocol by placing the magnetic coil underneath the subjects at the T9 spinal process with the subjects lying supine (fig 1).

Statistical Analysis

A region of interest was drawn on the images to exclude the esophagus and small intestine. This region of interest was used to plot the curves used for statistical comparisons. Gastric emptying times were measured in minutes. All data are presented as the mean ± standard error of the mean (SEM), and differences are considered significant at a *P* value less than .05. A 2-way repeated-measures analysis of variance (ANOVA) was performed on the percentage of gastric emptying values over time when comparing baseline and FMS protocols. When evaluating $GE_{t1/2}$ data, the paired *t* test was used to test between baseline and FMS protocols.

Table 1: Demographic Data of Able-Bodied Subjects

Subject	Age (y)	Sex	Weight (kg)	Height (cm)
1	41	M	83	187.5
2	28	M	68	170
3	49	M	70	173
4	19	M	82	178
5	21	M	64	173

Abbreviation: M, male.

RESULTS

Able-Bodied Subjects

All able-bodied subjects were men (table 1). The mean ± SEM of the $GE_{t1/2}$ at baseline and with FMS was 36±2.9 minutes and 33±3.1 minutes, respectively (fig 2). Comparing the data by using the paired *t* test, the $GE_{t1/2}$ of poststimulation was significantly shorter than the baseline $GE_{t1/2}$ ($P<.05$). The percentages of gastric emptying of the baseline protocol at 30, 60, 90, and 120 minutes were 22%±2.5%, 60%±3.2%, 77%±2.0%, and 89%±2.1%, respectively (fig 3). The percentages of gastric emptying at 30, 60, 90, and 120 minutes of the FMS protocol were 33%±2.8%, 60%±3.5%, 78%±3.6%, and 91%±2.6%, respectively. A repeated-measures ANOVA showed the percentages of gastric emptying at baseline and with FMS to be significantly different over the time course of the measurements ($P<.05$). Figure 4 shows an example of gastric emptying curves of an able-bodied subject at baseline and with FMS. The $GE_{t1/2}$ with FMS was accelerated by about 2 to 5 minutes when compared with the baseline values.

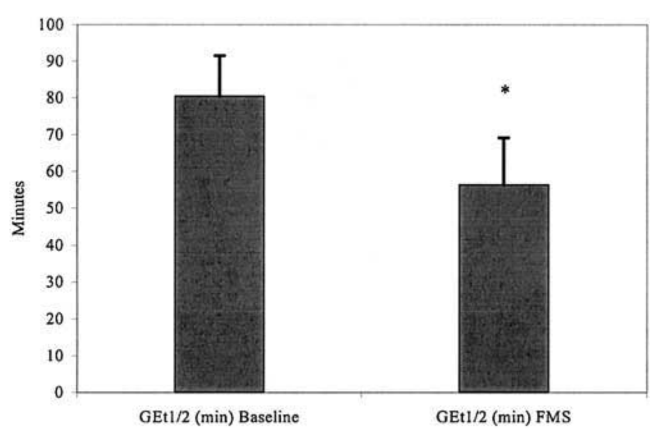

Fig 2. Comparison of $GE_{t1/2}$ between baseline and with FMS in able-bodied subjects (n=5). Data are mean ± SEM; the FMS group showed a significantly shorter measure of $GE_{t1/2}$. * $P<.05$.

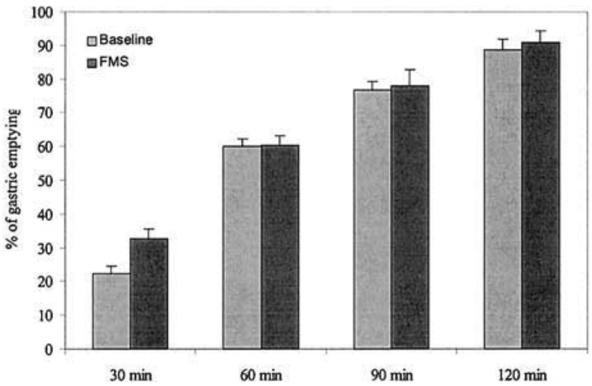

Fig 3. Comparison of percentage of gastric emptying between baseline and with FMS in a period of 2 hours in able-bodied subjects.

SCI Subjects

The mean age of SCI subjects was 42±5.8 years (table 2). The mean ± SEM of the $GE_{t1/2}$ at baseline and with FMS was 84±11.1 minutes and 59±12.7 minutes, respectively (P=.03) (fig 5). The percentages of gastric emptying of the baseline protocol at 30, 60, 90, and 120 minutes of study were 6%±2.9%, 16%±7.6%, 38%±5.2%, and 55%±6.7%, respectively (fig 6). The percentages of gastric emptying at 30, 60, 90, and 120 minutes of the FMS protocol were 26%±8.0%, 49%±10.2%, 61%±9.0%, and 69%±8.6%, respectively (fig 6). The repeated-measures ANOVA comparing the percentage of gastric emptying at baseline and FMS showed a significant difference (P<.01). Figure 7 shows an example of gastric emptying curves of an SCI subject at baseline and with FMS. The $GE_{t1/2}$ of gastric emptying with FMS was accelerated by approximately 25 minutes when compared with the baseline values.

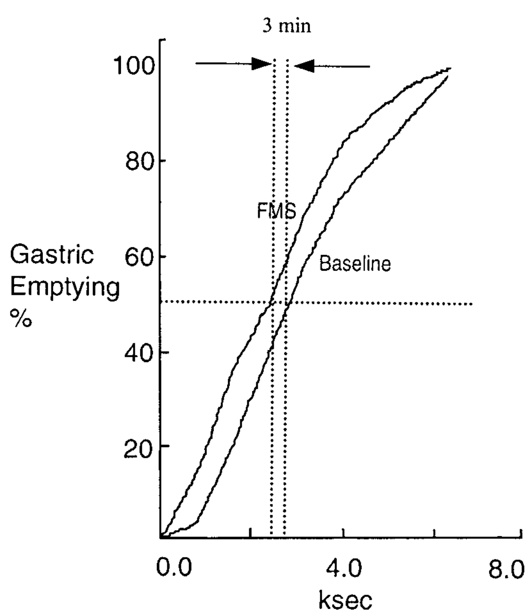

Fig 4. An example of the gastric emptying curves over time with and without FMS in 1 able-bodied subject.

Table 2: Demographic Data of SCI Subjects

Subject	Age (y)	Sex	Weight (kg)	Height (cm)	Level of Injury	ASIA
1	49	M	75	170	C5–7	B
2	52	M	79	170	C3–4	D
3	40	F	87	155	C4–5	B
4	26	M	72	173	C5–6	B

Abbreviations: M, male; F, female; ASIA, American Spinal Injury Association.

DISCUSSION

After food passes from the esophagus to the lower esophageal sphincter, it enters the stomach, in which it is mixed and transported to the duodenum. The stomach is composed of the fundus, body, antrum, and pylorus. The slow contraction of the fundus and the peristaltic waves in the body propel food to the antrum, which will then proceed to empty the partially digested food into the duodenum. The rate of gastric emptying is influenced by several factors including electrical activity, the composition of the meal, and the release of GI hormones.[20] The electrical activity is mediated by both parasympathetic and sympathetic nervous systems. In general, the vagus nerve (parasympathetic) functions to increase stomach motility, whereas the thoracolumbar splanchnic nerves (sympathetic) decrease stomach motility.

Impaired gastric emptying has been reported in SCI in most recent investigations,[5,6,21] although others showed unaltered gastric emptying.[22,23] This delay in gastric emptying in SCI, especially in tetraplegic patients, was thought to be partly caused by the excessive splanchnic sympathetic activity resulting from the disconnection above the level of the sympathetic outflow.[21] This finding was supported by Fealey et al[6] when they found an association between decreased antral motility and increased reflex splanchnic sympathetic activity (autonomic hyperreflexia) in the high-cord patient group. However, they did not observe any significant difference in the duration of the phases and cycle length of the migrating motor complex in the antrum between the high-cord group and normal controls. Thus, they attributed the delay in gastric emptying to the disturbance of the normal interdigestive antral-duodenal motor coordination resulting from SCI.[6] On the contrary, Lu et al[24]

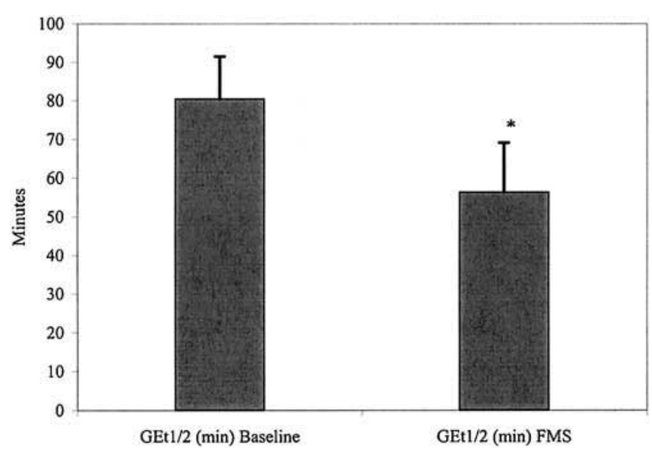

Fig 5. Comparison of $GE_{t1/2}$ between baseline and with FMS in SCI subjects (n=4). Data are mean ± SEM; the FMS group showed a significantly shorter measure of $GE_{t1/2}$. * P<.05.

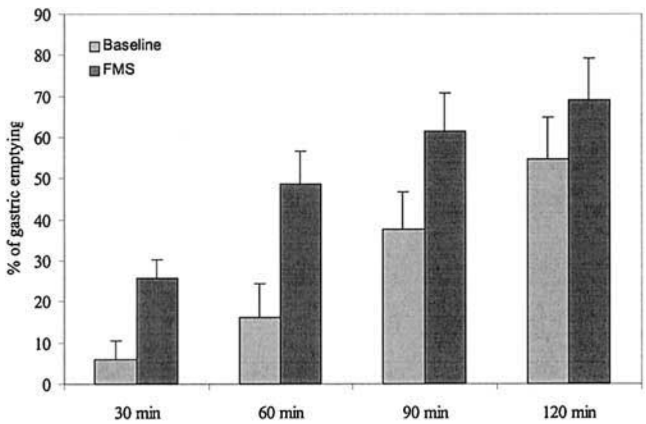

Fig 6. Comparison of percentage of gastric emptying between baseline and with FMS in a period of 2 hours in SCI subjects.

compared the gastric myoelectric activity of patients with cervical SCI with able-bodied controls, and found no significant difference between the 2 groups, either in the fasting or in the fed state. This unaltered gastric myoelectric activity after SCI was also supported by other animal data.[25,26]

Our study clearly shows that FMS enhances gastric emptying in patients with SCI. In all subjects using FMS, the $GE_{t1/2}$ decreased; in the SCI subjects, the $GE_{t1/2}$ decreased by more than one third. When considering the percentages of gastric emptying at different time intervals, it seems that FMS is most effective in improving gastric emptying during the first 30 minutes. In the able-bodied subjects, the percentages improved from 22%±2.5% to 33%±2.8% at 30 minutes (a 50% improvement); in the SCI subjects, the percentages increased from 6%±2.9% to 26%±8.0% (a 333% increase). This sharp enhancement in gastric emptying in the first 30 minutes may be because most FMS was applied within the first 40 minutes of the 2-hour protocol. When comparing the percentages of gastric emptying at 30 minutes between the able-bodied and SCI subjects, we found that FMS restored the gastric emptying time to normal in SCI subjects. We thus postulate that if the stimulation period were increased from 40 minutes to the entire protocol (2h), the percentages of gastric emptying in SCI might surpass that of the able-bodied subjects at the end of the 2-hour baseline protocol. If this can be shown, FMS would be shown to restore the impaired gastric emptying in SCI subjects to that of able-bodied subjects. This longer stimulation protocol is currently being performed in our laboratory.

The exact mechanism of the effect of FMS on gastric emptying has not been clearly elucidated. Based on our recent observations as well as what has been shown in the electric and magnetic stimulation literature, we have 2 theories. One theory is that FMS functions similarly to electric stimulation to accelerate gastric emptying through direct activation of the underlying gastric neuromuscular apparatus and/or even of the smooth muscle of the stomach. FMS may be acting in a similar manner as gastric pacing,[8,10,11] which uses electrodes implanted on the surface of the stomach muscle to cause rhythmic gastric contractions. In this study, we used stimulation parameters (stimulation frequency and duration) that are comparable to some of the published electric stimulation reports.[27,28]

The second theory that we postulate relates to the fact that rhythmic abdominal muscle contractions bring about improvement in gastric emptying. The thoracic spinal nerves that innervate abdominal muscles are activated as they exit the neuroforamen.[29] From our experience with FMS of the expiratory muscles, we found that lower thoracic magnetic coil placement produced significant expiratory function because the abdominal muscles (major expiratory agonists) were innervated by the lower thoracic spinal nerves.[30-32] In a recent animal investigation,[18] by applying a smaller figure of 8 coil near the thoracolumbar region, we found that FMS produced significant improvement in gastric emptying at 1 hour after orogastric gavage (90.4% in the experimental group vs 69.6% in the control group). In another FMS human protocol, performed by using the same magnetic stimulator and coil placement as in our study, we were able to observe a significant reduction in colonic transit time (from 105.2h at baseline to 89.4h).[16] All of the previously mentioned studies included protocols that stimulated lower thoracic spinal nerves, which undoubtedly stimulated the abdominal muscles. This information and the absence of gastric myoelectric activity in chronic SCI[24] lead us to postulate that the weakness of the abdominal musculature may be an important factor associated with delayed gastric emptying in patients with chronic SCI. The induction of abdominal muscle contractions may bring about improved gastric emptying and GI transits in a manner similar to other physical examples of external compressions that produce compressions of the internal organs (the compression of the heart from chest compressions during cardiac pulmonary resuscitation, and the compressions of the bladder from abdominal compressions to produce more effective bladder emptying).

When a time-varying magnetic field is applied in the vicinity of a conductive structure, it induces an electric field, the amplitude of which is related to the rate of change of the magnetic field and to the geometry of the conductive structure. This electric field creates a current that, if of appropriate amplitude and duration, can stimulate neuromuscular tissue as if it had been produced by electrodes. In our study, we showed that FMS accelerates gastric emptying in subjects with SCI and those without SCI. Like electric stimulation, FMS accelerated gastric emptying. Unlike electric stimulation, FMS does not require surgery, thus avoiding complications associated with surgery or chronic implants, such as infection and hemorrhage.

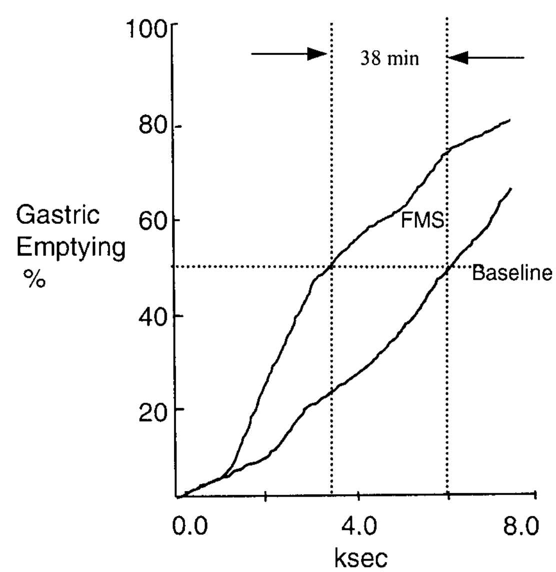

Fig 7. An example of the gastric emptying curves over time with and without FMS in 1 SCI subject.

The magnetic fields generated from the magnetic coil are able to pass through high-resistance structures such as bone, fat, and skin without harm to the body. FMS is easy to use; the coil can be placed outside of clothing. The magnetic stimulator is still quite bulky and expensive, which may limit its wide acceptance by patients who may benefit from this emerging technology. According to our experience, FMS is only beneficial to patients with preserved lower motoneuron function, as is the case in many patients with SCI or other central nervous system disorders.

CONCLUSION

We have shown that FMS facilitates gastric emptying in both able-bodied and SCI subjects. The mechanism of action by FMS may be quite similar to electric stimulation of the stomach, which results in rhythmic contractions of the stomach. The effective coil placement at T9 also showed the association between rhythmic abdominal muscle contractions and improved gastric emptying. FMS may be a very useful clinical tool for patients with upper motoneuron lesion and impaired gastric emptying.

Acknowledgments: We thank Jane Babbitt, MS, and Ellenore Palmer, PT, for their assistance during various portions of the study.

References

1. Stone JM, Nino-Murcia M, Wolfe VA, Perkash I. Chronic gastrointestinal problems in spinal cord injury patients: a prospective analysis. Am J Gastroenterol 1990;85:1114-9.
2. Schuster M. Motor disorders of the stomach. Med Clin North Am 1981;65:1269-89.
3. Segal JL, Brunnemann SR, Gordon SK, et al. Decreased theophylline bioavailability and impaired gastric emptying in spinal cord injury. Curr Ther Res 1985;38:831-46.
4. Segal JL, Milne N, Brunnemann SR, Lyons KP. Metoclopramide induced normalization of impaired gastric emptying in spinal cord injury. Am J Gastroenterol 1987;82:1143-8.
5. Segal JL, Milne N, Brunneman SR. Gastric emptying is impaired in patients with spinal cord injury. Am J Gastroenterol 1995;90: 466-70.
6. Fealey RD, Szurszewski JH, Merritt JL, DiMagno EP. Effect of traumatic spinal cord transection on human upper gastrointestinal motility and gastric emptying. Gastroenterology 1984;87:69-75.
7. Nimmo WS. Drugs, diseases and altered gastric emptying. Clin Pharmokinet 1976;1:189-203.
8. McCallum RW, Chen JD, Lin Z, Schirmer BD, Williams RD, Ross RA. Gastric pacing improves emptying and symptoms in patients with gastroparesis. Gastroenterology 1998;114:456-61.
9. Kelly KA, LaForce RC. Pacing the canine stomach with electrical stimulation. Am J Phys 1972;222:588-94.
10. Miedema BW, Sarr MG, Kelly KA. Pacing the human stomach. Surgery 1992;111:143-50.
11. Hocking MP, Vogel SB, Sninsky CA. Human gastric myoelectric activity and gastric emptying following surgery with pacing. Gastroenterology 1992;103:1811-6.
12. Hasler WL, Soudah HC, Dulai G. Mediation of hyperglycemic-evoked gastric slow-wave dysrhythmias by endogenous prostaglandin. Gastroenterology 1995;108:727-36.
13. Lin VW, Singh H, Chitkara RK, Perkash I. Functional magnetic stimulation for restoring cough in patients with tetraplegia. Arch Phys Med Rehabil 1998;79:517-22.
14. Lin VW, Hsiao IN, Zhu E, Perkash I. Functional magnetic stimulation for conditioning of expiratory muscles in patients with spinal cord injury. Arch Phys Med Rehabil 2001;82:162-6.
15. Lin VW, Wolfe V, Perkash I. Micturition by functional magnetic stimulation. J Spinal Cord Med 1997;20:218-26.
16. Lin VW, Nino-Murcia M, Frost F, Wolfe V, Hsiao I, Perkash I. Functional magnetic stimulation of the colon in patients with spinal cord injuries. Arch Phys Med Rehabil 2001;82:167-73.
17. Lin VW, Perkash A, Liu H, Todd D, Hsiao I, Perkash I. Functional magnetic stimulation: a new modality in enhancing systemic fibrinolysis. Arch Phys Med Rehabil 1999;80:545-59.
18. Lin VW, Hsiao I, Xu H, Bushnik T, Perkash I. Functional magnetic stimulation facilitates gastrointestinal transit of liquids in rats. Muscle Nerve 2000;23:919-24.
19. Nino-Murcia M, Friedland G. Functional abnormalities of the gastrointestinal tract in patients with spinal cord injuries: evaluation with imaging procedures. AJR Am J Roentgenol 1992;158: 279-81.
20. Malmud LS, Fisher RS, Knight LC, Rock E. Scintigraphic evaluation of gastric emptying. Semin Nucl Med 1982;7:116-25.
21. Kao C, Ho Y, Changlai S, Ding H. Gastric emptying in spinal cord injury patients. Dig Dis Sci 1999;44:1512-5.
22. Zhang RL, Chayes Z, Korsten MA, Bauman WA. Gastric emptying rates to liquid or solid meals appear to be unaffected by spinal cord injury. Am J Gastroenterol 1994;89:1856-8.
23. Rajendran SK, Reiser JR, Bauman W. Gastrointestinal transit after spinal cord injury: effect of cisapride. Am J Gastroenterol 1992; 87:1614-7.
24. Lu CL, Montgomery P, Zou X, Orr WC, Chen J. Gastric myoelectrical activity in patients with cervical spinal cord injury. Am J Gastroenterol 1998;93:2391-6.
25. Bueno L, Ferre JP, Ruckebusch Y. Effects of anesthesia and surgical procedures on intestinal myoelectrical activity in rats. Am J Dig Dis 1978;23:690-5.
26. Telford GL, Go VI, Szurszewski JH. Effect of central sympathectomy on gastric and small intestinal myoelectrical activity and plasma motilin concentrations in the dogs. Gastroenterology 1985; 89:989-95.
27. Johnson B, Familoni B, Abell TL, Werkman R, Wood G. Development of a canine model for gastric emptying [abstract]. Gastroenterology 1990;98:A362.
28. Grundfest-Broniatowski S, Davies CR, Oslen E, et al. Electrical control of gastric emptying in denervated and reinnervated canine stomach: a pilot study. Artif Organs 1990;14:254-9.
29. Maccabee PJ, Amassian VE, Eberle L, Rudell A, Cracco RQ, Lai KS. Measurement of the electric field induced into inhomogeneous volume conductors by magnetic coil: applications to human spinal geometry. Electroencephalogr Clin Neurophysiol 1991;81: 224-37.
30. Lin VW, Romaniuk JR, DiMarco AF. Functional magnetic stimulation of the respiratory muscles in dogs. Muscle Nerve 1998; 21:1048-57.
31. Lin VW, Hsieh C, Hsiao I, Canfield J. Functional magnetic stimulation of the expiratory muscles: a non-invasive and new method for restoring cough. J Appl Physiol 1998;84:1144-50.
32. Singh H, Magruder M, Bushnik T, Lin VW. Expiratory muscle activation by functional magnetic stimulation of the thoracic and lumbar spinal nerves. Crit Care Med 1999;27:2201-5.

Suppliers

a. Dupont, Dupont Bldg, 1007 Market St, Wilmington, DE 19898.
b. GE StarCam 400AC; GE Medical Systems, PO Box 44, Milwaukee, WI 53201.
c. Medtronic Inc, 710 Medtronic Pkwy, Minneapolis, MN 55432-5604.