**Introduction**

Impaired GI motility (in the absence of mechanical obstruction) is common amongst critically ill and post-operative patients, and recovery of bowel function is difficult to predict.

Despite recent advances in technology, GIT motility and function continues to be difficult to assess.

[<https://ccforum.biomedcentral.com/articles/10.1186/s13054-020-02889-4#MOESM4>]

* Clinical assessment
  + A screenshot of a computer

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  + Auscultation of bowel sounds is widely taught in medical students as part of the assessment for bowel function. However this study has shown that bowel sounds are NOT associated with flatus, bowel movement, or tolerance of oral intake in patients after major abdominal surgery
    - <https://pubmed.ncbi.nlm.nih.gov/28481855>
  + Bowel sounds also do NOT correlate with Ultrasound visualisation of peristalsis - there were many events where an auscultated sound failed to correlate with observed peristalsis, and vice versa.
    - <https://pubmed.ncbi.nlm.nih.gov/34150368>
* Gastric emptying
  + Table

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* Intestinal motility
  + Text, letter

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[<https://pubmed.ncbi.nlm.nih.gov/28086261/>]

Table

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Although some techniques are more established than others, there is "no validated imaging method for bedside monitoring" [<https://ccforum.biomedcentral.com/articles/10.1186/s13054-020-02889-4#MOESM4>], and there is a paucity of literature in correlating findings with return of bowel function (amongst critically ill or post-operative patients).

GI ultrasound is a promising area of study.

Ultrasound is non-invasive, rapid and repeatable without risk of radiation and with low risk of infectious cross contamination.

This paper details a protocol for ultrasound investigation of small bowel motility by assessment of occlusive & non-occlusive contractions, with the results of a pilot study validating the procedure and raising questions for its future use.

**Methods**

**Literature Review**

A literature search was performed using pubmed (see supplements). It found only 2 relevant articles.

[Prolonged intestinal transit and diarrhea in patients with an activating GUCY2C mutation.](https://pubmed.ncbi.nlm.nih.gov/28957388/) (2017)

Method

* Ultrasound Protocol for occlusive & non-occlusive contractions
  + Defined in their previous study [10]
  + 1 minute video recordings were obtained in the LUQ (jejunum) & RLQ (ileum)
  + Occlusive contraction = active indentation of bowel wall occluding the lumen
  + Non-occlusive contraction = active indentation in which luminal content can be observed between the anterior & dorsal wall
  + If the lumen was not fluid-filled, we were not able to differentiate between occlusive & non-occlusive contractions → the measurements were excluded
* Ultrasound protocol for counting fluid-filled small bowel loops
  + Used a commercially available magnetometer-based position and orientation measurement (POM) device on the ultrasound scanner which enabled tracking of the scan head in the magnetic field → this allows for generation of 3D image over a larger area
* "Snow-globe" phenomenon = small bowel segments with:
  + turbulent intraluminal & back-forth flow of content
  + non-occlusive contractions with no propulsive movements
* SMA resistive index (RI) was also measured - as a surrogate for measuring SMA blood flow

Results

* Significantly more non-occlusive contractions in the ileum observed in the Functional Gut Disorder Syndrome (FGDS) patients compared to Healthy Controls (HC)
* No difference in number of occlusive contractions between the two groups
* Significantly more "snow-globes" in FGDS patients

[A New Method for Evaluating Small Intestinal Motility Using Duplex Sonography](https://www.ajronline.org/doi/pdfplus/10.2214/ajr.168.1.8976944) (1997)

Method

* Fasting subjects
* Duplex doppler, & stethoscope auscultation in 3 abdominal sites, for 1minute each
  + Doppler gate was positioned intra-luminally near the gut wall - these signals were (in the author's opinion) different to those produced by blood flow, and represented the back & forth movements of the gut wall during
* Number of peristaltic waves & bowel sounds were compared
* A portion of subjects were re-measured after ingestion of 1.5L tap water and another portion after ingestion of a standard test meal
* On the basis of an analysis of amplitude and duration of the associated Doppler signals (using **arbitrarily selected cut-off values** for both parameters), intestinal movements observed in all three segments examined were classified as probably peristaltic (P waves) or probably non-peristaltic (non-P waves).
  + P waves = high amplitudes & ≥2sec
  + Non-P waves = unco-ordinated weak signals, low amplitudes, <2sec
  + Artifact due to passive movement of intestine (e.g. diaphragmatic movement, probe movement) were excluded

Results

|  |  |  |
| --- | --- | --- |
|  | 'Peristaltic' waves | 'Non-peristaltic' waves |
| Fasting | Average = 3 per min | Average = 3.5 per min |
| After ingestion of 1.5L tap water | Average = 3.78 per minute | Average = 6.2 per min |
| After ingestion of test meal | Average = 3.92 per minute | Average = 7.3 per min |

[Development of a quantitative method for evaluating small intestinal motility using ultrasonography in mice](https://www.jstage.jst.go.jp/article/expanim/68/3/68_19-0030/_pdf) (2019)

Method

* **US assessment of only duodenum in the longitudinal plane for 10sec** 
  + Trace-line placed on the boundary between proximal wall of duodenum & inner cavity
  + Locomotion activity of duodenal wall defined as average longitudinal displacement between any number of speckle points on the trace line for all time frames
    - Artifact caused by respiration was difficult to remove, so the average maximum displacement during 3breaths was calculated
  + Activity assess pre & post loperamide administration (15min, 30min, 60min)

A picture containing text, microscope

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Results

* n=6
* Loperamide = ↓duodenal motility & ↑dilation of duodenum

|  |  |  |
| --- | --- | --- |
|  | Average maximum displacement | Compared with control |
| Control | 0.32 ± 0.04 mm | - |
| Loperamide 15min | 0.17 ± 0.01 mm | P<0.05 |
| Loperamide 30min | 0.15 ± 0.02 mm | P<0.01 |
| Loperamide 60min | 0.19 ± 0.04 mm | P<0.05 |

[Ultrasonographic evaluation of the effects of the administration of neostigmine and metoclopramide on duodenal, cecal, and colonic contractility in Arabian horses](http://www.veterinaryworld.org/Vol.13/November-2020/22.pdf) (2020)

Method

* US assessment of descending duodenum, cecal body and colon
  + Duodenum = cross-sectional view of circular contractions (doesn't specify occlusive vs non-occlusive)
  + Caecal = based on moving of the caecal wall away from the transducer
  + Colon = changes in sacculations
* At each site, contractions were counted for 3min before treatment and at 15, 30, 60, 120 & 180min post-administration

Results

n=21 Egyptian Arabian horses, divided evenly into 3 groups

Table

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* Metoclopramide improves caecal & colonic contractions, but not duodenal
* Neostigmine improves duodenal, caecal & colonic contracts, however duration of effects lasts less than metoclopramide

**Research Question & Ultrasound Protocol**

Question = In critically ill abdominal trauma patients or post-operative abdominal surgery patients in the ICU setting, does ultrasound assessment of bowel contraction (brief vs. detailed protocol) correlate/predict with return of bowel function

Target Population = ICU patients (aiming for n=50)

* Abdominal trauma - bowel/mesenteric trauma vs all abdominal trauma
* Bowel surgery
* Abdominal surgery that involves lots of bowel handling (e.g. AAA, Urology, Gynae-Onc)

Ultrasound Protocol

* To count number of occlusive & non-occlusive bowel contractions
  + Target bowel = 'Visualised section of bowel' vs small bowel only
  + When to scan?
    - Within 24h post admission? Immediately on admission?
    - Repeat scan?
* Brief US scan protocol
  + von Volkmann: 1 minute video recordings obtained in the LUQ (jejunum) & RLQ (ileum)
  + Kishi: US assessment of duodenum
* Detailed US scan protocol
  + Lawn-mower approach (EFSUMB)
    - Text, letter

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* Diagram

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Return of bowel function definition/end-points

* Gastric residual volumes of NGT feeds (less than some arbitrary cut-off amount?)
* Time to tolerating NGT aspirates at target rate OR clinician determined feed tolerance
* Time to first bowel motion
* ?Nutrient absorption - e.g. first drop in potassium or phosphate?
* How to follow up this end point? Might be difficult after they leave ICU

Statistical correction/adjustment for potential variables

* Type of abdominal pathology/surgery
  + Bowel incisions vs. bowel handling
  + Laparotomy vs laparoscopic
  + ostomy creation vs not
* Intra-abdominal inflammation (peritonitis, sepsis)
* Peri-operative complications - bleeding, pneumonia, intra-abdominal abscess
* Factors that increase bowel wall edema (e.g. hypoalbuminemia, aggressive IVF)
* Opioid use & other constipating agents (e.g. ondansetron)
* etc

**Supplement**

PubMed Search: (ultrasound) AND ("gut motility") -> 35 papers

|  |  |  |
| --- | --- | --- |
| 1. | [Established and emerging methods for assessment of small and large intestinal motility.](https://pubmed.ncbi.nlm.nih.gov/28086261/)  Grønlund D, Poulsen JL, Sandberg TH, Olesen AE, Madzak A, Krogh K, Frøkjaer JB, Drewes AM.  Neurogastroenterol Motil. 2017 Jul;29(7). doi: 10.1111/nmo.13008. Epub 2017 Jan 13.  PMID: 28086261 Review. | Not relevant (full article read) |
| 2. | [Motility alterations in celiac disease and non-celiac gluten sensitivity.](https://pubmed.ncbi.nlm.nih.gov/25925923/)  Pinto-Sanchez MI, Bercik P, Verdu EF.  Dig Dis. 2015;33(2):200-207. doi: 10.1159/000371400. Epub 2015 Apr 22.  PMID: 25925923 Review. | Not relevant |
| 3. | [Modeling intestinal disorders using zebrafish.](https://pubmed.ncbi.nlm.nih.gov/28129846/)  Zhao X, Pack M.  Methods Cell Biol. 2017;138:241-270. doi: 10.1016/bs.mcb.2016.11.006. Epub 2017 Jan 7.  PMID: 28129846 Review. | Not relevant. Not related to US |
| 4. | [Randomised controlled trial of trophic feeding and gut motility.](https://pubmed.ncbi.nlm.nih.gov/10325814/)  McClure RJ, Newell SJ.  Arch Dis Child Fetal Neonatal Ed. 1999 Jan;80(1):F54-8. doi: 10.1136/fn.80.1.f54.  PMID: 10325814 **Free PMC article.** Clinical Trial. | Not relevant.  Gastric emptying was assessed on ultrasound. Whole gut motility was assessed with a marker (carmine red) |
| 5. | [Acute physiological and electrical accentuation of vagal tone has no effect on pain or gastrointestinal motility in chronic pancreatitis.](https://pubmed.ncbi.nlm.nih.gov/28615966/)  Juel J, Brock C, Olesen SS, Madzak A, Farmer AD, Aziz Q, Frøkjær JB, Drewes AM.  J Pain Res. 2017 May 31;10:1347-1355. doi: 10.2147/JPR.S133438. eCollection 2017.  PMID: 28615966 **Free PMC article.** | Not relevant. |
| 6. | [Role of the interstitial cells of Cajal in the control of gut motility.](https://pubmed.ncbi.nlm.nih.gov/9112890/)  Hagger R, Finlayson C, Jeffrey I, Kumar D.  Br J Surg. 1997 Apr;84(4):445-50.  PMID: 9112890 Review. | Can't access full article.  Not relevant |
| 7. | [Gut transit time, using radiological contrast imaging, to predict early signs of necrotizing enterocolitis.](https://pubmed.ncbi.nlm.nih.gov/32244249/)  Chen W, Sun J, Kappel SS, Gormsen M, Sangild PT, Aunsholt L.  Pediatr Res. 2021 Jan;89(1):127-133. doi: 10.1038/s41390-020-0871-0. Epub 2020 Apr 4.  PMID: 32244249 | Not relevant |
| 8. | [Unexplained vomiting: a diagnostic challenge.](https://pubmed.ncbi.nlm.nih.gov/6378006/)  Malagelada JR, Camilleri M.  Ann Intern Med. 1984 Aug;101(2):211-8. doi: 10.7326/0003-4819-101-2-211.  PMID: 6378006 Review. | Not relevant |
| 9. | [Prolonged intestinal transit and diarrhea in patients with an activating GUCY2C mutation.](https://pubmed.ncbi.nlm.nih.gov/28957388/)  von Volkmann HL, Brønstad I, Gilja OH, R Tronstad R, Sangnes DA, Nortvedt R, Hausken T, Dimcevski G, Fiskerstrand T, Nylund K.  PLoS One. 2017 Sep 28;12(9):e0185496. doi: 10.1371/journal.pone.0185496. eCollection 2017.  PMID: 28957388 **Free PMC article.** | Seems relevant!  "Before and after a meal occlusive and non-occlusive contractions were obtained using ultrasound" |
| 10. | [Wireless capsule motility: comparison of the SmartPill GI monitoring system with scintigraphy for measuring whole gut transit.](https://pubmed.ncbi.nlm.nih.gov/19655250/)  Maqbool S, Parkman HP, Friedenberg FK.  Dig Dis Sci. 2009 Oct;54(10):2167-74. doi: 10.1007/s10620-009-0899-9. Epub 2009 Aug 5.  PMID: 19655250 | Not relevant |
| 11. | [Endoscopic full-thickness muscle biopsy for rectal tissue sampling in patients with severe gut motility disorders: an initial experience (with video).](https://pubmed.ncbi.nlm.nih.gov/30639538/)  Ngamruengphong S, Thompson E, McKnight M, Yang J, Pasricha PJ.  Gastrointest Endosc. 2019 Jun;89(6):1242-1247.e1. doi: 10.1016/j.gie.2019.01.001. Epub 2019 Jan 9.  PMID: 30639538 | Not relevant |
| 12. | [Diseases of the abdomen.](https://pubmed.ncbi.nlm.nih.gov/3516329/)  Rantanen NW.  Vet Clin North Am Equine Pract. 1986 Apr;2(1):67-88. doi: 10.1016/s0749-0739(17)30733-2.  PMID: 3516329 | Can't access full article.  Animal study (horses)  There **may be relevant** material on US for gut motility |
| 13. | [Evaluation of gut motility in type II diabetes by the radiopaque marker method.](https://pubmed.ncbi.nlm.nih.gov/10824881/)  Iida M, Ikeda M, Kishimoto M, Tsujino T, Kaneto H, Matsuhisa M, Kajimoto Y, Watarai T, Yamasaki Y, Hori M.  J Gastroenterol Hepatol. 2000 Apr;15(4):381-5. doi: 10.1046/j.1440-1746.2000.02076.x.  PMID: 10824881 Clinical Trial. | Not relevant |
| 14. | [Searching a role for endoscopic ultrasonography in Barrett's esophageus and other acid-related or gastrointestinal motility disorders.](https://pubmed.ncbi.nlm.nih.gov/17921959/)  Odegaard S.  Minerva Med. 2007 Aug;98(4):409-15.  PMID: 17921959 Review. | Can't access full article  **May be relevant** |
| 15. | [Gastric emptying of preterm neonates receiving domperidone.](https://pubmed.ncbi.nlm.nih.gov/19648772/)  Gounaris A, Costalos C, Varchalama E, Kokori F, Grivea IN, Konstantinidi K, Syrogiannopoulos GA.  Neonatology. 2010;97(1):56-60. doi: 10.1159/000231517. Epub 2009 Jul 31.  PMID: 19648772 Clinical Trial. | Can't access full article  Does not seem relevant. Abstract appears to focus on gastric emptying. |
| 16. | [Intestinal gas distribution determines abdominal symptoms.](https://pubmed.ncbi.nlm.nih.gov/14633947/)  Harder H, Serra J, Azpiroz F, Passos MC, Aguadé S, Malagelada JR.  Gut. 2003 Dec;52(12):1708-13. doi: 10.1136/gut.52.12.1708.  PMID: 14633947 **Free PMC article.** Clinical Trial. | Not relevant. Does not use ultrasound |
| 17. | [Gastrointestinal motility during cardiopulmonary bypass: a sonomicrometric study.](https://pubmed.ncbi.nlm.nih.gov/16836736/)  Gu YJ, de Kroon TL, Elstrodt JM, Rakhorst G.  Artif Organs. 2006 Jul;30(7):548-53. doi: 10.1111/j.1525-1594.2006.00257.x.  PMID: 16836736 | Not relevant (full article read)  Animal study (pigs) |
| 18. | [Serum ghrelin is associated with early feeding readiness but not growth in premature infants.](https://pubmed.ncbi.nlm.nih.gov/33935112/)  Kopp T, Codipilly C, Potak D, Fishbein J, Lamport L, Kurepa D, Weinberger B.  J Neonatal Perinatal Med. 2022;15(1):147-154. doi: 10.3233/NPM-200664.  PMID: 33935112 | Not relevant |
| 19. | [Colonic transit studies: normal values for adults and children with comparison of radiological and scintigraphic methods.](https://pubmed.ncbi.nlm.nih.gov/19488763/)  Southwell BR, Clarke MC, Sutcliffe J, Hutson JM.  Pediatr Surg Int. 2009 Jul;25(7):559-72. doi: 10.1007/s00383-009-2387-x. Epub 2009 Jun 2.  PMID: 19488763 Review. | Not relevant |
| 20. | [Establishment of human metastatic colorectal cancer model in rabbit liver: A pilot study.](https://pubmed.ncbi.nlm.nih.gov/28475639/)  Prieto V, Ludwig JM, Farris AB, Nagaraju GP, Lawal TO, El-Rayes B, Kim HS.  PLoS One. 2017 May 5;12(5):e0177212. doi: 10.1371/journal.pone.0177212. eCollection 2017.  PMID: 28475639 **Free PMC article.** | Not relevant |
| 21. | [Neurocutaneous melanosis associated with Hirschsprung's disease in a male neonate.](https://pubmed.ncbi.nlm.nih.gov/16080919/)  Iwabuchi T, Shimotake T, Furukawa T, Tsuda T, Aoi S, Iwai N.  J Pediatr Surg. 2005 Aug;40(8):E11-3. doi: 10.1016/j.jpedsurg.2005.05.030.  PMID: 16080919 | Not relevant |
| 22. | [New developments in the evaluation of gastroduodenal motility with special reference to duodenogastric reflux and its clinical significance.](https://pubmed.ncbi.nlm.nih.gov/6382578/)  Johnson AG, Eyre-Brook IA.  Scand J Gastroenterol Suppl. 1984;96:27-36.  PMID: 6382578 Review. | Not relevant |
| 23. | [Weight loss and delayed gastric emptying following a South American herbal preparation in overweight patients.](https://pubmed.ncbi.nlm.nih.gov/11424516/)  Andersen T, Fogh J.  J Hum Nutr Diet. 2001 Jun;14(3):243-50. doi: 10.1046/j.1365-277x.2001.00290.x.  PMID: 11424516 Clinical Trial. | Not relevant. Focuses on gastric emptying |
| 24. | [Postnatal intestinal disturbances in small-for-gestational-age premature infants after prenatal haemodynamic disturbances.](https://pubmed.ncbi.nlm.nih.gov/10772281/)  Robel-Tillig E, Vogtmann C, Faber R.  Acta Paediatr. 2000 Mar;89(3):324-30.  PMID: 10772281 | Not relevant |
| 25. | [Recombinant human neurotrophic factors accelerate colonic transit and relieve constipation in humans.](https://pubmed.ncbi.nlm.nih.gov/10889153/)  Coulie B, Szarka LA, Camilleri M, Burton DD, McKinzie S, Stambler N, Cedarbaum JM.  Gastroenterology. 2000 Jul;119(1):41-50. doi: 10.1053/gast.2000.8553.  PMID: 10889153 Clinical Trial. | Not relevant |
| 26. | [Nuclear transit studies of patients with intractable chronic constipation reveal a subgroup with rapid proximal colonic transit.](https://pubmed.ncbi.nlm.nih.gov/21763843/)  Yik YI, Cain TM, Tudball CF, Cook DJ, Southwell BR, Hutson JM.  J Pediatr Surg. 2011 Jul;46(7):1406-11. doi: 10.1016/j.jpedsurg.2011.02.049.  PMID: 21763843 | Not relevant |
| 27. | [Slow-transit constipation with concurrent upper gastrointestinal dysmotility and its response to transcutaneous electrical stimulation.](https://pubmed.ncbi.nlm.nih.gov/21373802/)  Yik YI, Clarke MC, Catto-Smith AG, Robertson VJ, Sutcliffe JR, Chase JW, Gibb S, Cain TM, Cook DJ, Tudball CF, Hutson JM, Southwell BR.  Pediatr Surg Int. 2011 Jul;27(7):705-11. doi: 10.1007/s00383-011-2872-x. Epub 2011 Mar 4.  PMID: 21373802 Clinical Trial. | Not relevant |
| 28. | [[Evaluation of small intestinal motility].](https://pubmed.ncbi.nlm.nih.gov/8211047/)  Turberg Y, Dederding JP.  Schweiz Med Wochenschr Suppl. 1993;54:26-31.  PMID: 8211047 French, German. | Not relevant.  Also original article in French & German. |
| 29. | [Prenatal hemodynamic disturbances -- pathophysiological background of intestinal motility disturbances in small for gestational age infants.](https://pubmed.ncbi.nlm.nih.gov/12101499/)  Robel-Tillig E, Vogtmann C, Bennek J.  Eur J Pediatr Surg. 2002 Jun;12(3):175-9. doi: 10.1055/s-2002-32723.  PMID: 12101499 | Not relevant |
| 30. | [The impact of transcutaneous electrical stimulation therapy on appendicostomy operation rates for children with chronic constipation--a single-institution experience.](https://pubmed.ncbi.nlm.nih.gov/22813807/)  Yik YI, Leong LC, Hutson JM, Southwell BR.  J Pediatr Surg. 2012 Jul;47(7):1421-6. doi: 10.1016/j.jpedsurg.2012.01.017.  PMID: 22813807 | Not relevant |
| 31. | [Patterns of gastric emptying in dysmotility-like dyspepsia.](https://pubmed.ncbi.nlm.nih.gov/7638564/)  Bortolotti M, Bolondi L, Santi V, Sarti P, Brunelli F, Barbara L.  Scand J Gastroenterol. 1995 May;30(5):408-10. doi: 10.3109/00365529509093299.  PMID: 7638564 | Not relevant. Focuses on gastric emptying |
| 32. | [[Gastric myoelectric activity disturbance in patients with traumatic lesions of the brain stem].](https://pubmed.ncbi.nlm.nih.gov/15174250/)  Thor PJ, Madroszkiewicz D, Moskała M, Madroszkiewicz E, Gościński I.  Neurol Neurochir Pol. 2003 Sep-Oct;37(5):1037-45.  PMID: 15174250 Polish. | Not relevant |
| 33. | [How common is colonic elongation in children with slow-transit constipation or anorectal retention?](https://pubmed.ncbi.nlm.nih.gov/22813806/)  Yik YI, Cook DJ, Veysey DM, Tudball CF, Cain TM, Southwell BR, Hutson JM.  J Pediatr Surg. 2012 Jul;47(7):1414-20. doi: 10.1016/j.jpedsurg.2012.01.007.  PMID: 22813806 | Not relevant |
| 34. | [Abomasal size and emptying time in healthy lambs and in lambs affected by watery mouth.](https://pubmed.ncbi.nlm.nih.gov/4060541/)  Eales FA, Small J, Murray L, McBean A.  Vet Rec. 1985 Sep 28;117(13):332-5. doi: 10.1136/vr.117.13.332.  PMID: 4060541 | Not relevant. |
| 35. | [Four cases of desmosis coli: severe chronic constipation, massive dilatation of the colon, and hypoperistalsis due to of changes in the colonic connective-tissue net.](https://pubmed.ncbi.nlm.nih.gov/11956799/)  Hübner U, Meier-Ruge W, Halsband H.  Pediatr Surg Int. 2002 Mar;18(2-3):198-203. doi: 10.1007/s003830100694.  PMID: 11956799 | Not relevant |

PubMed search: Ultrasound AND ("gut motility" OR "GIT motility" OR "GI motility") -> 85 papers (greyed out ones are repeated from above)

|  |  |  |
| --- | --- | --- |
| 1. | [ACG and CAG Clinical Guideline: Management of Dyspepsia.](https://pubmed.ncbi.nlm.nih.gov/28631728/)  Moayyedi P, Lacy BE, Andrews CN, Enns RA, Howden CW, Vakil N.  Am J Gastroenterol. 2017 Jul;112(7):988-1013. doi: 10.1038/ajg.2017.154. Epub 2017 Jun 20.  PMID: 28631728 Review. | Not relevant |
| 2. | [Gastrointestinal dysmotility disorders in critically ill dogs and cats.](https://pubmed.ncbi.nlm.nih.gov/26822390/)  Whitehead K, Cortes Y, Eirmann L.  J Vet Emerg Crit Care (San Antonio). 2016 Mar-Apr;26(2):234-53. doi: 10.1111/vec.12449. Epub 2016 Jan 28.  PMID: 26822390 Review. | Animal study.  **~May be relevant**  Can't access full article |
| ~~3.~~ | [~~Modeling intestinal disorders using zebrafish.~~](https://pubmed.ncbi.nlm.nih.gov/28129846/)  ~~Zhao X, Pack M.~~  ~~Methods Cell Biol. 2017;138:241-270. doi: 10.1016/bs.mcb.2016.11.006. Epub 2017 Jan 7.~~  ~~PMID: 28129846 Review.~~ |  |
| ~~4.~~ | [~~Established and emerging methods for assessment of small and large intestinal motility.~~](https://pubmed.ncbi.nlm.nih.gov/28086261/)  ~~Grønlund D, Poulsen JL, Sandberg TH, Olesen AE, Madzak A, Krogh K, Frøkjaer JB, Drewes AM.~~  ~~Neurogastroenterol Motil. 2017 Jul;29(7). doi: 10.1111/nmo.13008. Epub 2017 Jan 13.~~  ~~PMID: 28086261 Review.~~ |  |
| ~~5.~~ | [~~Motility alterations in celiac disease and non-celiac gluten sensitivity.~~](https://pubmed.ncbi.nlm.nih.gov/25925923/)  ~~Pinto-Sanchez MI, Bercik P, Verdu EF.~~  ~~Dig Dis. 2015;33(2):200-207. doi: 10.1159/000371400. Epub 2015 Apr 22.~~  ~~PMID: 25925923 Review.~~ |  |
| 6. | [Quantified small bowel motility in patients with ulcerative colitis and gastrointestinal symptoms: a pilot study.](https://pubmed.ncbi.nlm.nih.gov/32806922/)  Tufvesson H, Dreja J, Ekberg O, Leander P, Månsson S, Ohlsson B.  Acta Radiol. 2021 Jul;62(7):858-866. doi: 10.1177/0284185120946713. Epub 2020 Aug 17.  PMID: 32806922 | Not relevant (MRE only) |
| 7. | [An easy and low-cost biomagnetic methodology to study regional gastrointestinal transit in rats.](https://pubmed.ncbi.nlm.nih.gov/33544465/)  Pinto L, Soares G, Próspero A, Stoppa E, Biasotti G, Paixão F, Santos A, Oliveira R, Miranda J.  Biomed Tech (Berl). 2021 Feb 3;66(4):405-412. doi: 10.1515/bmt-2020-0202. Print 2021 Aug 26.  PMID: 33544465 | Not relevant  Animal study |
| 8. | [Functional lumen imaging probe in gastrointestinal motility diseases.](https://pubmed.ncbi.nlm.nih.gov/31498966/)  Chen HM, Li BW, Li LY, Xia L, Chen XB, Shah R, Abdelfatah MM, Jain A, Cassani L, Massaad J, Keilin S, Cai Q.  J Dig Dis. 2019 Nov;20(11):572-577. doi: 10.1111/1751-2980.12818. Epub 2019 Oct 16.  PMID: 31498966 Review. | Not relevant |
| ~~9.~~ | [~~Gut transit time, using radiological contrast imaging, to predict early signs of necrotizing enterocolitis.~~](https://pubmed.ncbi.nlm.nih.gov/32244249/)  ~~Chen W, Sun J, Kappel SS, Gormsen M, Sangild PT, Aunsholt L.~~  ~~Pediatr Res. 2021 Jan;89(1):127-133. doi: 10.1038/s41390-020-0871-0. Epub 2020 Apr 4.~~  ~~PMID: 32244249~~ |  |
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