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Alexander et al. 2009 International Systematic Review N=7 studies	**Objective:** To review specific objectives and processes to evaluate SCI outcome measures with psychometric properties, such as internal and external validity, developed by spinal cord injury organizations (i.e., ASIA, ICCP, ICORD, ISCoS and SCOPE). **Methods:** a framework was used for the appraisal of evidence	1. Most of the information found assessing colon and rectal function included anal manometry, rectal EMG, rectal impedance planimetry and colonic transit time. These methods provide valuable information about anorectal physiology, but their use is limited by extensive equipment needs and a lack of psychometric properties. 2. Total or segmental colorectal transit times determined by oral intake of radio-opaque markers and subsequent abdominal X-rays have been extensively used; however, the reproducibility and the association between colorectal transit times and bowel symptoms remain to be described. 3. The Neurogenic Bowel Dysfunction Score has been used in populations of people with SCI (the NBD score was subsequently validated for adult patients with SCI). 4. The Fecal Incontinence Scales includes QoL measures (participant response questionnaires), attempting to quantify participation, but were not specifically designed or validated for SCI. 5. A Cochrane review concluded that treatment of bowel dysfunction in central neurological diseases must

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		remain empirical, until large well-designed trials have been carried out.
Emmanuel et al. 2009 UK Cohort Level 2 N=81; N=55 with SCI	**Objective:** Bowel dysfunction is common after spinal cord injury (SCI). We aimed to determine whether hindgut testing of autonomic innervation provides insight into presence of symptoms, altered motor function (transit) and level of injury. **Population:** N=55 with SCI (45 male, mean age 36, range 19-68 y); Complete SCI (mean time since injury 34 months, range 13-134) N=24 (18 male, mean age 34) had lesions above T5 N=31 (27 male, mean age 37) had lesions below T5 N=26 non-SCI controls (17 female; mean age 36, range 18-61) **Treatment:** Underwent laser Doppler flowmetry **Outcome Measures:** Laser Doppler studies of rectal mucosal blood flow**,** Radio-opaque marker transit study to measure whole gut transit, assessment of rectal sensation measured by balloon distention and electrosensation measured by bipolar ring electrode, Anal sphincter manometry to	1. 32/55 SCI participants had slow whole gut transit. People with subjective constipation had significantly more retained markers than those without (mean markers 49 vs 22, respectively, p=0.007). 2. Rectal electrosensory thresholds were more abnormal in those with slow transit vs. normal transit (65.3 vs 44.1 mA, respectively, P<0.04). 3. Transmucosal rectal sensation was abnormal in all patients, significantly greater in those complaining of constipation compared with those without (67.3 vs 41.6 respectively, p<0.01). 4. SCI participants with constipation had significantly lower mucosal blood flow than asymptomatic SCI participants (mean 183 vs 267 FU, n=55, p<0.04). 5. The participants with slow transit had lower blood flow than did those with measured normal transit (mean 180 vs 273 FU, n=55, slow vs normal transit P<0.03). 6. Compared to control, resting blood flow was greater in participants with lesions above T5 (200 vs 238, respectively, p=0.056) and similar in those

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	assess anorectal parameters	with lesions below T5 (203 vs 213 FU, respectively, p=0.345).
Park et al. 2013 Korea Cohort Level 2 N=44	**Objective:** To evaluate the usefulness of plain abdominal radiography as an evaluation method for bowel dysfunction in patients with spinal cord injury (SCI). **Population:** 44 people with SCI (39 males and 5 females). Mean age: 50.2±16.9y (range 22-76 y) Mean time since injury: 23±37.8 months 11 complete SCI, 33 incomplete SCI. 22 cervical, 17 thoracic, 5 lumbar 11 AIS A, 8 AIS B, 10 AIS C, 14 AIS D, 1 AIS E **Treatment:** To evaluate the usefulness of plain abdominal radiography as an evaluation method for bowel dysfunction in patients with spinal cord injury (SCI). **Outcome Measures:** Starreveld scores and Leech scores were used to examine the degree of stool retention, analyzed from the plain abdominal radiographs. Constipation score was measured using the Rome II Diagnostic Criteria. Colonic transit time was measured using 1 capsule of Kolomark with 20 marker	1. As right colon transit time increased, stool retention score at ascending colon increased; as left colon transit time increased, stool retention score at descending colon increased ($p<0.05$). 2. As rectosigmoid colon transit time increased, stool retention score at the transverse colon decreased ($p<0.01$). 3. As right colon transit time increased, stool retention score at ascending colon increased; as left colon transit time increased, stool retention score at descending colon increased ($p<0.01$). 4. As total colon transit time increased, both the Starreveld score ($p<0.05$) and Leech score ($p<0.01$) significantly increased. 5. Starreveld score measured with the plain abdominal radiograph was 3.4±0.7 at the ascending colon; 1.8±0.86 at the transverse colon, 2.83±0.82 at the descending colon, and 2.14±1.0 at the rectosigmoid colon. It was measured as 10.19±2.45 at the total colon. 6. Leech score was 3.28±0.7 at the right colon, 2.8±0.8 at the left colon, and 2.35 ± 0.85 at the rectosigmoid colon. It was

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	rings with radio-opacity for 3 days at 9am.	measured as 8.45±1.83 at the total colon. 7. Megacolon was identified in 14 people at the ascending colon. Megarectum was identified in 11 people. 5 people showed both megacolon and megarectum. Group with megacolon had CTT of 60.60± 12.03 vs. group without megacolon with CTT 49.17 ± 20.56 ($p<0.05$). 8. Rectosigmoid colon and colon transit times according to the presence/absence of megarectum did not show a statistically significant difference.
Kim et al. 2016b Korea Prospective controlled trial Level 2 N=32	**Objective:** The aim of this study was to determine the efficacy of measuring the diameter and area of the rectum using ultrasonography as an additional parameter for the evaluation of neurogenic bowel in patients with spinal cord injury (SCI). **Population:** N=16 UMNB Female: 25% Age: 63.4 ± 12.7 y Level: 100% cervical Severity: 1 ASIA A, 0 ASIA B, 2 ASIA C, 13 ASIA D Time since injury: 132.7 ± 178.6 Days N=16 LMNB group Female: N= 5 Age: 47.9 ± 13.9 y	1. Comparing both groups, patients in the UMNB group had a significantly smaller mean rectal diameter than those in the LMNB group after defecation ($P = 0.022$) 2. There was a significant difference in rectal area reduction after defecation between the UMNB and LMNB groups ($p=0.005$) 3. Rectal diameter was significantly reduced after defecation in the UMNB group ($p=0.023$) but not in the LMNB group ($p=0.735$)

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	Level: 8 cervical 4 thoracic 4 lumbar Severity: 6 ASIA A 1ASIA B 1 ASIA C 8 ASIA D Time since injury: 44.7 ± 49.5Y **Treatment:** Ultrasound was applied on the abdomen and measured the diameter and area of the rectum were measured twice each before and after defecation, respectively. **Outcome Measure:** Ultrasonography to measure the diameter and area of the rectum to evaluate NBD in SCI.	
Putz et al. 2020 Germany Cohort Level 2 N=20	**Objective:** The main aim of this study is to evaluate whether magnetic resonance (MR) defecography can provide objective parameters correlating with the clinical manifestations of neurogenic bowel dysfunction (NBD) in participants with SCI. **Population:** 20 participants with sensorimotor complete traumatic AIS-A SCI with neurological level of injury between T1-T10, previously included in the MR defecography feasibility study (Putz et al. 2017)	1. People suffering from frequent incontinence episodes had higher anorectal angle (ARA) values at rest (p=0.00018) and hiatal descent (M-line) values at rest (p=0.045) compared to those with rare incontinence episodes. 2. For people without NBD, pelvic floor parameters increased from rest to defecation. 3. 9/20 people with SCI had abnormal pelvic floor movement, indicated by negative delta for either ARA, H and M (from resting to defecation values). 4. Those who had abnormal pelvic floor movement showed a trend

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	Treatment: Previously published MR defecography parameters (anorectal angle (ARA), hiatal descent (M-line) and hiatal width (H-line)) of twenty participants with SCI were now compared to a standardized clinical assessment of NBD. Descriptive statistics, correlations and t-tests for independent samples were calculated. **Outcome Measures:** MR-defecography procedure to measure pelvic floor parameters: by 2 images of the pelvic floor (one at rest and one during defecation) where differences were calculated for ARA, hiatal descent, and hiatal width of the levator plate.	toward more severe NBD presentation (higher mean NBD score of 15 compared to 11 in people without any negative parameter values (p=0.061). 5. Other parameters such as age, time since injury, level of injury, and routine bowel evacuation practice had no correlation to the obtained parameters.
Putz et al. 2017 Germany Cohort Level 2 N=20	**Objective:** To investigate whether MR-defecography can be employed in sensorimotor complete spinal cord injury (SCI) subjects as a potential diagnostic tool to detect defecational disorders associated with neurogenic bowel dysfunction (NBD) using standard parameters for obstructed defecation. **Population:**	1. MR-defecography was feasible in all participants. 2. Measurement results: Mean anorectal angle (ARA) and hiatal width (H-line) were significantly increased at rest and evacuation in comparison to non-SCI reference values (p<0.001). 3. Significant increase of mean levator plate (M-line) descent

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	Sensorimotor complete traumatic SCI, AIS-A, and level of injury between T1-T10. Time since injury was mean 20y (range 3-50y). 2/20 participants female. Mean age 47y (range 19-70y) **Treatment:** Defecation was successfully induced by eliciting the defecational reflex after rectal filling with ultrasonic gel, application of two lecicarbon suppositories and digital rectal stimulation. Examination was performed with patients in left lateral decubitus position using T2-weighted turbo spin echo sequence in the sagittal plane at rest (TE 89ms, TR 3220ms, FOV 300mm, matrix 512×512, ST 4mm) and ultrafast-T2-weighted-sequence in the sagittal plane with repeating measurements (TE 1.54ms, TR 3.51ms, FOV 400mm, matrix 256×256, ST 6mm). Changes of anorectal angle (ARA), anorectal descent (ARJ) and pelvic floor weakness were documented and measured data was compared to reference values of asymptomatic non-SCI subjects in the literature to assess feasibility. **Outcome Measures:** MR-defecography as a diagnostic tool to detect defecation	during induced defecation ($p<0.001$).

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	disorders associated with NBD in people with sensorimotor complete SCI. Grading systems for pelvic floor weakness, including hiatal widening, levator plate descent and rectal descent. All images analyzed for the presence of anterior rectocele and vesiocele.	
Williams et al. 2012 USA Prospective controlled trial Level 2 N=20	**Objective:** To assess whether SmartPill technology can be applied in persons with SCI. **Population:** N=20 SCI (10% female) 12 paraplegia (mean age 52±14 years; mean duration of injury 15±11 years; 8 complete motor/sensory and 4 incomplete motor/sensory) 8 tetraplegia (mean age 41±9 years; mean duration of injury 14±12 years; 4 complete motor/sensory injury and 4 incomplete) 10 non-SCI (8 male 2 female; 40±12 years). **Outcome measures:** SmartPill capsule tracked gastric emptying time (GET), colonic transit time (CTT), whole gut transit time (WGTT), maximum gastric acidity.	1. GET, CTT, and WGTT were prolonged in the SCI group compared to the non-SCI group (10.6±7.2 vs 3.5±1.0h, P<0.01; 52.3±42.9 vs 14.2±7.6 h, P=0.01; 3.3±2.5 vs 1.0±0.7 days, P<0.01; respectively). 2. Minimum values of gastric pH were similar in SCI and non-SCI group (1.1±0. 8 vs 1.0±0.8 pH units, P>0.6, respectively). 3. No significant differences in GET, CTT, WGTT, and maximum gastric acidity between paraplegia and tetraplegia groups.
Fynne et al. 2012 Denmark Prospective controlled trial Level 2	**Objective:** To study orocecal transit time and gastric emptying (GE) in patients with SCI. **Population:**	1. The magnetic pill reached cecum in only 3/19 participants with SCI during the 6-hour protocol vs. 11/15 in the control group (p<0.001).

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N=34; N=19 with SCI	N=19 with SCI; median age 54 y; median time since injury 75 months (range 10-528); 7 complete, 12 incomplete; 8 level of injury above T6; 3 ASIA A, 3 ASIA C, 2 ASIA D 11 at the conus medullaris or cauda equine (3 ASIA A, 4 ASIA B, 2 ASIA C, 2 ASIA D) N=15 non-SCI; median age 32 y **Treatment:** Subjects ingested a small magnetic pill that subsequently was tracked by the Motility Tracking System - MTS-1 (Motilis, Lausanne, Switzerland). **Outcome Measures:** Ingested magnetic pill was tracked by the Motility Tracking System to measure orocecal transit time, and bowel motility patterns.	2. Median orocecal transit time was > 360 min in people with SCI vs 340 min in the control group (p<0.001). 3. Orocecal transit time was prolonged in people with low SCI (p<0.01) and high injury (p<0.01) compared to people in the control group. 4. No significant difference in gastric emptying between people with SCI (median 35 min, range 10-232) and the control group (median 25 min, range 1-135) (p=0.60). Frequency of gastric contractions was the same for people with SCI and the control group (median 2.9 per min range 2.7-3.1, median 2.9 per min range 1.7-3.2, respectively; p=0.30). Basic frequency of small intestinal contractions was the same in SCI (median 10/min, range 10-15) and the control group (median 10/min, range 9-11) (p=0.30).
Krogh et al. 2000 Denmark Prospective controlled trial Level 2 N=26; N=10 SCI	**Objective:** To compare total gastrointestinal transit times (GITT) and segmental colorectal transit times (CTT) in SCI patients with acute and chronic lesions to those of healthy volunteers. Furthermore, to examine the impact of time elapsed since injury on GITT and CTT, and finally to compare the pattern of colorectal dysfunction in	1. Median colorectal emptying during defecation was 81% of the counts within the rectosigmoid in controls vs. 27% of the counts within the rectosigmoid in people with conal/cauda equina lesions reporting normal defecation (n=6; p<0.001). 2. Median antegrade transport was significantly different between the control group and conal/cauda equina lesion group

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	patients with supraconal versus conal/cauda equina lesions. **Population:** N=10 SCI (6 men, 4 women, age 21-57y, median 36 y); all had lesions of the conus medullaris (n=8) or the cauda equina (n=2); 1 motor/sensory complete, 9 motor/sensory incomplete; time since injury 3 mo-9y (median 4y); 8 traumatic injury, 2 disc prolapse N=16 non-SCI controls (10 men, 6 women, age 22-42y, median 30y) **Treatment:** Patients took 10 radioopaque markers on six consecutive days and an abdominal X-ray was taken on day 7. GITT and CTTs were computed from the number of markers in the entire colorectum and in each colorectal segment respectively. **Outcome Measures:** Colorectal scintigraphy and radio-opaque markers to measure colonic transit times at defecation and through each colorectal segment; degree of colonic emptying	reporting normal defecation without clysma (n=6) for the rectosigmoid (82% vs. 27%, respectively, p<0.001) and descending colon (38% vs 4%, respectively; p<0.02). 3. The transverse and caecum/ascending colon did not show significant differences in median antegrade transport between the groups. 4. The cumulated transit time of the segments was significantly longer in people with SCI (median 2.7 days; range 0.2-4.2 days) than the control group (median 0.7 days; range 0-1.4 days) (p<0.05).
Trivedi et al. 2016 UK Cohort Level 2 N=44; N=24 SCI	**Objective:** Supraconal spinal cord injury (SCI) and lower motor neurone spinal cord injury (LMN-SCI) cause bowel dysfunction; colorectal	1. Three-way analysis showed that those with complete SCI level above T5 had significantly lower anal resting pressure (46±10

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	compliance may further define its pathophysiology. The aim of this study was to investigate rectal (RC) and sigmoid (SC) compliance and anorectal physiology parameters, in these subjects. **Population:** SCI N=24 18 complete SCI 6 incomplete SCI 8 complete SCI level above T5 10 Complete SCI level below T10 Control Group: N=20 Female: 60% Age: 44 (23-78)y SCI group: individuals with supraconal SCI and bowel dysfunction were recruited. Median age (range): 45 (24-66)y Female: 41.7%. 13 individuals had LMN- **Treatment:** Staircase distensions were performed using a barostat. Anorectal manometry, including rectoanal inhibitory reflex (RAIR) measurement, was performed in all. **Outcome Measures:** NBD bowel symptoms, rectoanal inhibitory reflex (RAIR), rectal (RC) and sigmoid (SC) compliance	cmH_2O vs. 79±7 cmH_2O, $P<0.05$) compared to those with level below T10 and controls. 2. Incomplete SCI participants had a similar relaxation amplitude to controls, whereas complete SCI led to a significantly greater reduction in percentage amplitude compared with both controls ($p<0.01$) and incomplete SCI ($p<0.01$). 3. Three-way analysis between controls, complete, and incomplete SCI showed no differences in compliance. 4. Analysis of complete SCI above T5 and below T10 revealed that those with SCI above T5 had higher RC compared with both controls and those with injury below T10 ($p<0.05$). 5. Mean rectal compliance (RC) in SCI was significantly higher than in controls ($p<0.05$), and significantly lower in LMN-SCI than in controls ($p=0.0021$). 6. SC was also significantly higher in SCI compared with controls ($p=0.0021$). Those with complete SCI level above T5 had a significantly higher SC than controls ($p<0.01$). No significant difference in SC between LMN-SCI and control groups.

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