

# Dolichocolon (redundant colon) in a rhesus macaque (*Macaca mulatta*)

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## Abstract

Dolichocolon (redundant colon) is an underdiagnosed cause of severe constipation in humans. The clinical presentation reported here in a rhesus macaque closely resembles that of intestinal adenocarcinoma, the most common neoplasia in macaques. Dolichocolon should be considered in differential diagnosis of macaques with anorexia, weight loss, and constipation.

## KEYWORDS

colon, dolichocolon, non-human primates, redundant colon, rhesus macaque

## 1 | INTRODUCTION

In current human medical practice, endoscopists, radiologists, and gastrointestinal surgeons frequently report the presence of a redundant colon<sup>1</sup> as a secondary finding on gastrointestinal exploration and procedures. The general medical consensus defines dolichocolon as an anatomic abnormality involving an elongated colon with redundancies in one or more segments of the colon. The extra length forms tortuosities and kinks, and it is often related to constipation and abdominal discomfort. The real prevalence of dolichocolon in humans is unknown, mainly due to a lack of population-based investigations,<sup>2</sup> with most publications on dolichocolon being case reports and low-level case series.<sup>1</sup> While the etiology remains unclear,<sup>1,2</sup> some reports suggest a possible congenital etiology.<sup>2</sup> However, studies in mice<sup>3,4</sup> indicate that the bowel's fecal transport characteristics could contribute to the pathogenesis of dolichocolon.

Dolichocolon is a known cause of slow transit constipation in humans.<sup>5-7</sup> The most frequent symptoms include bloating and abdominal discomfort. Since the symptoms derive from colonic dysfunction and prolonged transit times, the condition is frequently underdiagnosed. A colonic transit study with barium contrast, a radiopaque marker test (sitz marker study) or a CT colonography is required for definitive diagnosis.<sup>2,8</sup>

## 2 | CASE REPORT

A 10-year-old naive research female rhesus macaque (*Macaca mulatta*) presented with a 700g body weight loss during a routine semiannual examination. Abdominal palpation revealed an intestinal thickening with fecal accumulation in the right cranial abdomen. Radiographs confirmed the presence of a moderate amount of stool accumulation. CBC showed no alterations, but blood biochemistry revealed elevated ALT (94 U/L) and moderately low total protein (6.5 mg/dL). The macaque was routinely fed a commercial primate diet (Teklad 2050, Innotiv) supplemented with fresh vegetables, fruits and other enrichment items daily, and no abnormalities in appetite or fecal production were noted prior to the routine exam. The initial differential diagnosis included GI stenosis/obstruction due to radiolucent foreign body, neoplasia, endometriosis, abdominal granuloma, and inflammatory enteropathies.

Fecal occult blood test (Hemoccult®) and tuberculin skin test were negative. Fecal production was confirmed, but small dry feces were observed, confirming mild to moderate dehydration. Supplemental hydration was provided through the addition of a flavored electrolyte solution (Pedialyte®) to the drinking water and a fiber supplement consisting of 2 prunes and one fiber supplement biscuit (Metamucil®) per day.

Two weeks later, a follow-up exam revealed an additional weight loss of 600g. The enlarged portion of the GI tract and the fecal accumulation palpated longer (approximately 15 cm). A new set of radiographs revealed severe colonic stool burden with gas distention in the proximal small intestine (Figure 1), and no evidence of metastatic nodules in the thorax. Abdominal ultrasound confirmed previous findings and no evidence of endometriosis. Blood biochemistry showed ALT returned to normal range, but lower total protein (5.4 mg/dL) with a considerable drop in globulin (1.5 g/dL), while albumin (3.9 g/dL) remained stable. Based on the rapid decline in body weight and the hypoproteinemia an exploratory laparoscopic procedure was scheduled.

After a 12h fasting, the animal was sedated with a single dose of ketamine (8 mg/kg IM) and midazolam (0.2 mg/kg IM) and prepared for laparoscopic surgery. Analgesia was provided with Carprofen (4 mg/kg SQ) and a single dose of extended-release buprenorphine (0.2 mg/kg SC). Isoflurane anesthesia was maintained through a 4.5 ED endotracheal tube and mechanical ventilation. The laparoscopic exploration was performed through three 5 mm diameters trocars; one was placed in the linea alba (3 cm cranially to the umbilicus), and the other two approximately 7 cm caudolateral to the first. Abdominal pressure was maintained at 8 mmHg during the exploration. Laparoscopy findings demonstrated no evidence of gastrointestinal neoplasia, but a detailed evaluation of the large intestine revealed the presence of dolichocolon and secondary severe colonic stool burden that involved the entire length of the colon and the distal ileum.

The animal recovered uneventfully, and a more aggressive laxative treatment was initiated by adding sennosides (7.5 mg/PO/SID) to the previously established fiber supplements. Metoclopramide (0.2 mg/kg/PO/SID) was added 72h later. After 7 days of treatment and 2 days of abundant fecal production, metoclopramide and sennosides were discontinued. The animal remained on fiber dietary supplements to maintain adequate GI motility. Six weeks later the body weight and blood work had returned to baseline levels, and no evidence of constipation was noted.

Six months later, during the next scheduled routine exam, 50 mL of barium sulfate oral suspension (Liquid E-Z-PAQUE®) mixed with

50mLs of a highly palatable liquid diet (Ensure®) were syringe fed 2.5h prior to sedation to perform a colon transit study. The study delineated significant colon redundancies that formed kinks and tortuosity, especially along the transverse colon (Figure 2).

### 3 | DISCUSSION

Rhesus macaques are among the most frequent non-human primate species used in biomedical research and are commonly affected by naturally occurring colon disorders like idiopathic chronic diarrhea<sup>9</sup> and intestinal adenocarcinoma.<sup>10-12</sup> To the knowledge of the authors, this is the first reported case of dolichocolon in this species.

Dolichocolon is generally a benign condition with treatment often centered on the constipation associated with the slow colonic transit. Treatment consists of fiber-rich diet supplementation, adequate water intake to maintain an adequate colonic transit, and support from prokinetic/laxative medication for moderate to severe constipation cases. Surgical intervention is generally not required, and mainly considered when colonic loops are twisted (colonic volvulus). Colonic volvulus can lead to gangrene and perforation and accounts for up to 15% of the human large bowel obstructions in the US and western Europe.<sup>13</sup>

The presentation of redundant colon in this rhesus macaque shares common symptomatology (anorexia, weight loss, constipation, hypoproteinemia, hypoalbuminemia) with the most frequent neoplasia in older rhesus macaques, intestinal adenocarcinoma.<sup>11</sup> Adenocarcinoma is most frequently localized in the cecum, ileocecal junction, and transverse colon, and requires early diagnosis and surgical resection to minimize risk of metastasis. Contrast radiographs can reveal a characteristic annular constricting lesion in cases of intestinal adenocarcinoma, or a segmental stricture at the ileocecal junction that is highly suggestive of malignancy.<sup>12</sup>

Given the frequently benign nature of dolichocolon, the ability to diagnose it via non-invasive techniques (colonic transit studies) and effective dietary/medical management options to control symptoms, this condition has a much more favorable prognosis in

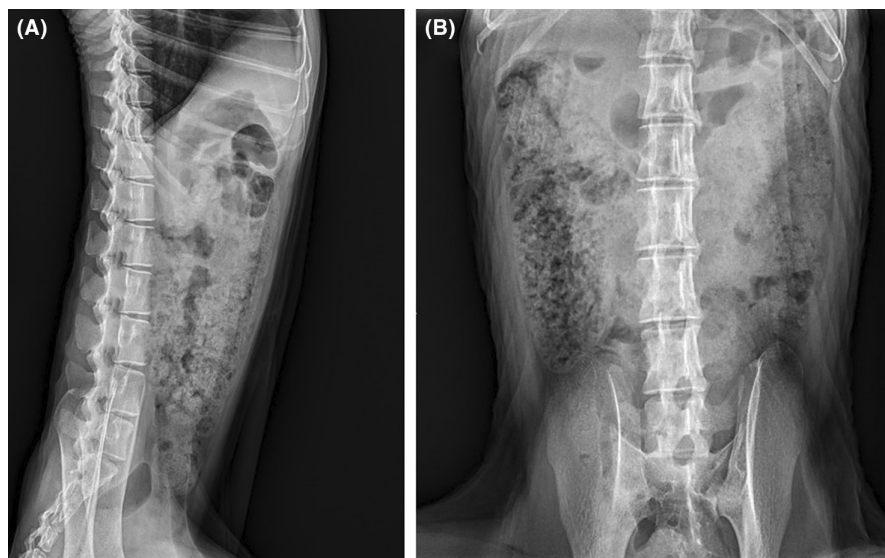
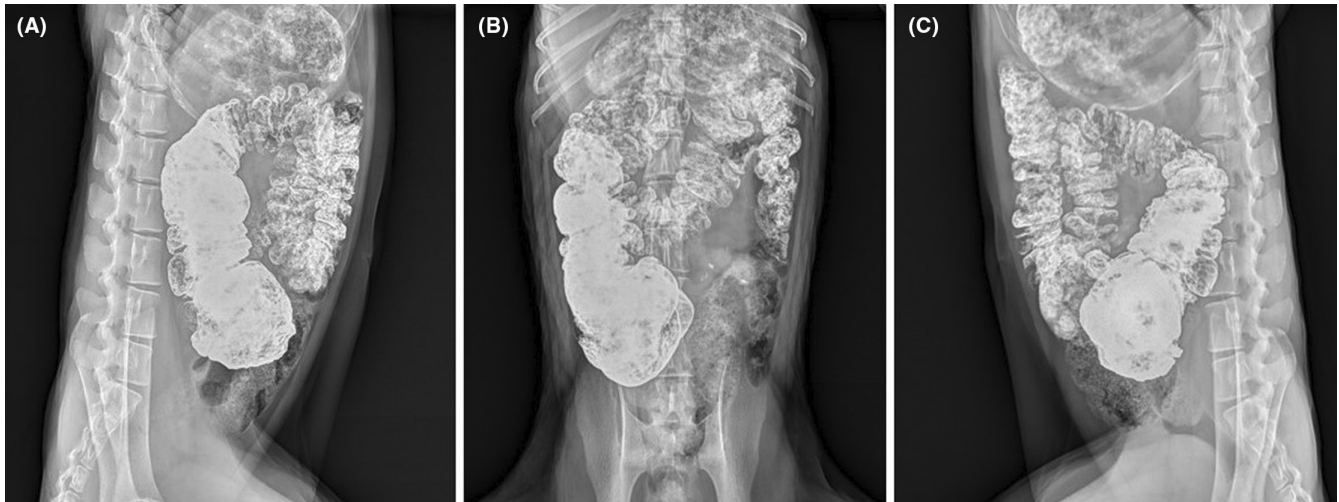


FIGURE 1 Abdominal radiographic exploration. 2 weeks after the initial exploration. (A) Lateral view and (B) ventrodorsal view. Note the presence of severe constipation and the palpable consolidation in the right lateral abdomen.



**FIGURE 2** Barium contrast colonic study. (A) Lateral view left lateral recumbency, (B) ventrodorsal view, and (C) lateral view, right lateral recumbency. Note the enlarged cecum and ascending colon, and the colonic redundancies originating kinks and tortuosity, especially along the transverse colon.

comparison with intestinal adenocarcinoma. Therefore, we believe that dolichocolon should be included in the differential diagnosis of older rhesus macaques presenting with weight loss and constipation, to minimize the chances of a misdiagnosis.

The authors confirm that the ethical policies of the journal, as noted on the journal's author guidelines page, have been adhered to, and the appropriate ethical review committee approval has been received. The US National Research Council's guidelines for the Care and Use of Laboratory Animals were followed.

#### CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

#### DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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