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Gastrointestinal transit times in young and old cats

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Abstract

Ageing results in a decrease in apparent nutrient digestibility in the gastrointestinal (GI) tract. The aim of this study was to investigate whether the rate of gastric emptying or total GI transit times differed between young (3.0 ± 0.9 years) and senior (11.6 ± 1.4 years) cats. Gastric emptying rates were measured using [1-^{13}C]octanoic acid and total transit times with chromium oxide. No significant differences ($P > 0.05$) were observed in either the rate of gastric emptying or total transit time between young and senior cats although senior cats exhibited a larger variability in total transit time compared to the younger cats (35.71 ± 14.06 and 26.46 ± 5.80 h, respectively). The results of this study indicate that the observed reduction in nutrient digestibility in ageing cats is not due to alterations in the rate of passage of digesta through the GI tract.

Keywords: Ageing; Cat; Chromium oxide; Feline; Gastric emptying; Gastrointestinal transit time; Stable isotope; Octanoic acid

1. Introduction

Ageing is a complex biological mechanism affecting the entire body. One effect of ageing is a decrease in apparent nutrient digestibility in the gastrointestinal (GI) tract (Montgomery et al., 1978). This has been observed in many species including humans (Yuasa et al., 1995), rats (Holt and Dominquez, 1981) and cats (Taylor et al., 1995). The decrease in nutrient digestibility with age may be due to several factors including changes in the composition of bile, decreased enzymatic secretion and activity, intestinal epithelial atrophy or altered gastric emptying rates and GI transit times (Saltzman and Russell, 1995). Gastric emptying is affected by many factors including pH, meal size, and meal content (Gainsborough et al., 1993), and studies in humans and rats have demonstrated significant decreases in gastric emptying with increasing age (Smits and Lefebvre, 1995; Clarkston et al., 1997).

Total transit time encompasses gastric emptying rate and both small intestinal and colonic retention times. One of the main functions of the small intestine is to digest and absorb nutrients. A fast transit time through the small intestine could lead to reduced digestibility and malabsorption of nutrients, while a slower transit time may result in bacterial overgrowth. The main functions of the colon are absorption of excess water from the waste products and storage of these products in the rectum until expulsion. One of the main factors to affect colonic transit time is smooth mus-

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cle activity. Slow transit times and the associated low faecal output have been linked as probable causative factors in large bowel cancer and gallstones (Probert et al., 1995), and in humans, it is reported that the elderly have more frequent bouts of constipation (Saltzman and Russell, 1995). Studies investigating the effect of ageing on GI transit times in humans indicated that older subjects had a slower mean colonic time compared to younger subjects (Madsen, 1992). These findings have also been observed in rats, with results showing a decrease in stool mass and slower colonic transit times (up to 70%) with an increase in age (Varga, 1976; Smits and Lefebvre, 1995).

There have been no studies investigating the effect of ageing on GI transit times in cats. Therefore the aim of this study was to examine whether GI transit time was altered with age. Gastric emptying rates and total transit times were examined in healthy female adult cats aged 2–13 years using non-invasive markers incorporated into food. It is hypothesised that the age-related decreases in nutrient digestibility observed previously in cats (Taylor et al., 1995) could be due to altered GI transit times.

2. Materials and methods

2.1. Animals

British domestic short-haired cats bred in a barrier breeding unit at the WALTHAM Centre for Pet Nutrition were used. Six young (3.0 ± 0.9 years; mean $\pm$ S.D.) and six senior (11.6 ± 1.4 years) female neutered cats (*Felis domesticus*) were individually housed. The cats were given a routine health check, including biochemical and haematological tests before the start of the trial to ensure all were clinically healthy.

2.2. Measurement of gastric emptying rate

The cats were fed a standard canned cat food (Whiskas™) ad libitum, for a minimum of 5 days preceding the test. After an overnight fast, the cats were weighed and approximately 5 mg/kg bodyweight of [1-^{13}C]octanoic acid (99 at.% ^{13}C; Euriso-Top, France) was mixed into 10 g food and offered to the cat (test meal). Once eaten (usually within 1 min), the cats were offered an additional 40 g of food which was normally eaten within 5 min. ^{13}C-labelled octanoic acid is an accepted non-radioactive substrate for measuring gastric emptying rate (10). Once [1-^{13}C]octanoic acid enters the small intestine it is quickly absorbed and the fatty acid metabolised and ^{13}C released (Ghoos et al., 1994). After oxidation, $^{13}CO_2$ mixes with the body pool of CO_2–HCO_3 and breathed out. Breath samples were collected from the cats using a rubber mask which fitted snugly over the nose and mouth. The mask was attached via a two-way valve to a 350 ml collection bag allowing the inhalation of atmospheric air, and the collection of exhaled air. Duplicate breath samples were removed from the bag via a tap attached to a 30 ml glass syringe and transferred into 12 ml evacuated tubes (Exetainers, Labco, High Wycombe). These were stored at room temperature until analysed. Two samples were collected immediately before administration of the isotope to obtain background $^{13}CO_2$ enrichment levels. Following the meal, samples were collected at 10 min intervals for 5 h, timed from when the test meal was consumed. Isotopic enrichment of the breath was determined as atom percent (at.%) by isotope ratio mass spectrometry (IRMS) (20–20 Europa Scientific, Crewe, UK). Total CO_2 production was determined by whole body indirect calorimetry (Peachey et al., 1999). Peak production of $^{13}CO_2$ and percent recovery of administered dose was then calculated.

2.3. Calculations

$$^{13}CO_2 \text{ expired (mmol/min)} = \frac{\text{atom\%}_{t1} - \text{atom\%}_{t0}}{100} \times \text{total } CO_2 \text{ (mmol/min)} \quad \text{(a)}$$

(where: $t1$ = time of breath collection (min); $t0$ = background).

Production of $^{13}CO_2$ was calculated from the area under the curve produced from $^{13}CO_2$ expired (mmol/min) plotted against time (mins) (2)

$$\% \text{ recovery of administered dose} = \frac{\text{Total } ^{13}\text{C produced}}{\text{Total } ^{13}\text{C administered}} \times 100, \text{ (Klein, 1991).} \quad \text{(c)}$$

2.4. Total transit time

Chromium oxide (a non-digestible, non-absorbable marker) was used to measure total transit time. Chromium oxide can be clearly seen in the faeces voided and is quantified by atomic absorption spectrophotometry.

Total transit time was measured 5 days after the gastric emptying trial during which time the cats were given free access to a standard canned cat food between 09:00–10:00 h and 14:00–15:00 h. During the trial period, cats were individually housed to allow individual faecal collection. After an overnight fast, 0.05 g Cr_2O_3 (BDH, Derby, UK) was mixed thoroughly into 10 g food, and offered to each cat (09:00 h) followed by an additional 40 g food (as for the gastric emptying trial). Cats were next allowed access to food between 14:00 and 15:00 h as normal. All faeces voided over the next 72-h period were collected separately and stored at 4°C. Video equipment and infra-red lighting were used in order to determine the exact time of defecation. Transit time was measured in each cat on four separate occasions over a 14-week period to allow for variability.

Individual faecal samples were freeze dried, finely ground and ashed at 550°C for 3 h. The ash samples were prepared for chromium analysis as described by Siddons et al. (1985). The chromium content of the samples were determined on an atomic absorption spectrophotometer (Spectra AA20, Varian, Walton-on-Thames, Surrey, UK) against potassium dichromate standards (20–100 ppm Cr). Total transit time was estimated as the time from ingestion of the test meal to the time of defecation of faeces with peak chromium content.

2.5. Statistical analysis

The effect of age on the rate of $^{13}CO_2$ release from [1-^{13}C]octanoic acid was tested using one-way analysis of variance (ANOVA). As total transit time was measured in each cat on four separate occasions, the effect of age was tested using one-way ANOVA, with cats as blocks. Results were considered to be significant at $P < 0.05$ (Statgraphics Plus 2.1, Statistical Graphics Corporation).

3. Results

The biochemical and haematological profiles of all the cats were within the normal range. Table 1 gives the body weight for the young and senior cats and the mean quantity of food consumed during the gastric emptying and transit time studies. There were no differences in body weight between the young and senior cats. The [^{13}C]octanoic acid and chromium oxide test meals were readily and completely consumed. Similar intakes of the 40 g meal were observed for young and senior cats during the total transit time study, but senior cats had significantly lower mean intakes during the gastric emptying study ($P = 0.05$).

3.1. Gastric emptying

Table 2 presents the data for peak $^{13}CO_2$ production and the recovery of ^{13}C administered in young and senior cats. No significant differences ($P > 0.1$) were observed between young and senior cats for peak $^{13}CO_2$ production or for total $^{13}CO_2$ produced. Fig. 1 shows the mean profile of $^{13}CO_2$ production in young and senior cats over the 5 h

Table 1
Bodyweights and food intakes for the young and senior cats (mean ± S.D.)

	Senior cats $n = 6$	Young cats $n = 6$	P-value*
Age (years)	11.6 ± 1.4	3.0 ± 0.9	0
Body Weight (kg)	3.42 ± 0.47	3.37 ± 0.59	0.89
Test meal ([1-^{13}C]octanoic acid) (g)	10 ± 0	10 ± 0	0
Follow-up meal eaten (g)	35.0 ± 5.1	39.7 ± 0.8	0.05
Test meal (chromium oxide) (g)	10 ± 0	10 ± 0	0
Follow-up meal eaten (g)	38.45 ± 1.75	37.21 ± 1.73	0.24

* One-way ANOVA.

Table 2
Recovery of administered ^{13}C relating to gastric emptying in young and senior cats (mean ± S.D.)

	Senior cats $n = 6$	Young cats $n = 6$	P-value*
^{13}C-octanoic acid administered (μmol/kg BW)	40.81 ± 5.82	41.40 ± 6.85	0.87
Total CO_2 production (mmol/h)	54.02 ± 4.62	60.27 ± 11.71	0.25
Resting energy expenditure (kJ/h)	28.93 ± 2.67	32.23 ± 6.08	0.10
Time peak $^{13}CO_2$ production (min)	63.3 ± 11.7	56.7 ± 9.8	0.31
Peak $^{13}CO_2$ production (μmol/min)	0.31 ± 0.81	0.25 ± 0.14	0.37
Total $^{13}CO_2$ production (μmol)	54.17 ± 5.67	47.31 ± 19.85	0.43
Total % recovery of administered dose	40.00 ± 8.49	35.61 ± 15.79	0.56

* One-way ANOVA.

trial period. The $^{13}CO_2$ production rate was similar in both young and senior cats, suggesting that the rate of gastric emptying was similar in young and senior cats.

3.2. Total transit times

Cats had access to food for 1 h in the morning and afternoon, so any influence of meal time on total transit time could be standardised. There were no significant differences ($P = 0.06$) in feed intake between the young and senior cats (212 ± 32.0 and 175 ± 26.1 g, respectively). Table 3 presents the data for total transit times in young and senior cats. There were no significant differences ($P > 0.05$) between the number of defecations in the 72-h period, the faecal dry matter content or the total transit times in young and senior cats.

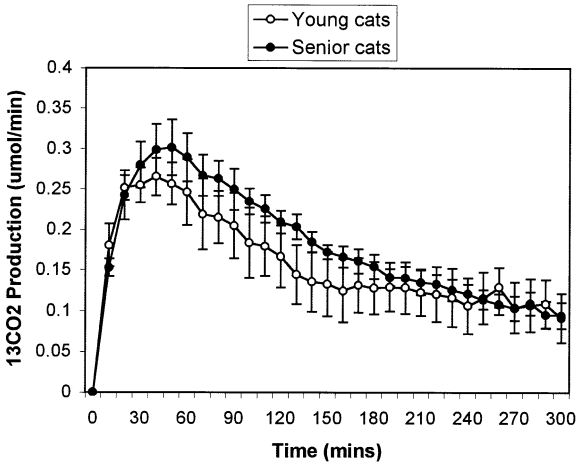

Fig. 1. Breath $^{13}CO_2$ enrichment production over 300 min measured in six young and six senior cats following a test meal of [1-^{13}C]octanoic acid.

Total transit times, however, were more variable in senior cats (35.7 ± 14.1 h) compared to the younger cats (26.5 ± 5.8 h).

4. Discussion

This study examined the rate of gastric emptying and total GI transit times in cats, to determine whether alterations in digesta passage rate may contribute to the age-related decreases in nutrient digestibility. The markers used were accepted non-invasive markers to measure transit times (Sharpe and Robinson, 1970; Maes et al., 1994).

Evidence reported in the literature of changes in gastric emptying rate and transit times with age is conflicting. Some differences may be due to methodology, others may be due to the huge individual variability, seen in both rats and humans. Goggin et al. (1998), demonstrated that gastric emptying rate in cats is affected by both meal size and the physical nature of the food (wet or dry diet). In the present study, all cats were

Table 3
Total transit time data (mean ± S.D.)[a]

	Senior cats $n = 6$	Young cats $n = 6$	P-value*
Number of defecations in 72 h	2 ± 0.7	3 ± 0.5	0.29
Faecal dry matter (%)	32.25 ± 7.30	33.36 ± 3.61	0.74
Total transit time (h)	35.71 ± 14.06	26.46 ± 5.80	0.17

[a] Mean of four measurements per cat.
* One-way ANOVA (effect of cat blocked).

offered a 50 g meal, including the test meal, which supplied around 15% of their daily energy requirement. Although small, this meal size is typical for many cats, as they tend to consume frequent small meals when given free access to food rather than to 'meal feed' which is characteristic of some mammalian species (Mugford and Thorne, 1980). No differences were observed in the gastric emptying rates between young and senior cats. This corroborates results from studies in both humans (Moore et al., 1983; Gainsborough et al., 1993) and rats (Yuasa et al., 1995) where ageing was reported to have no effect on the rate of gastric emptying, although significant differences have been reported by others (Smits and Lefebvre, 1995; Clarkston et al., 1997). The time of peak $^{13}CO_2$ production in the present study (57–63 min) corresponded closely with the results of Goggin et al. (1998), where peak gastric emptying time was estimated at around 61min in cats aged 2–5 years. Similar recoveries of administered isotope (35%) were reported by Maes et al. (1996), in a study on gastric emptying rates in humans.

Total GI transit time varied between 26.5 and 35.7 h, although senior cats exhibited greater individual variability than younger cats. Other studies have reported total transit times of around 40 h in cats (Fucci et al., 1995). The present study could not determine the individual rates between the small or large intestine, but a recent study by Papasouliotis et al., (1998), assessed the effect of ageing on orocecal transit time in cats by measuring breath hydrogen content. The principle of this technique is based on the microbial fermentation of undigested carbohydrate in the colon, producing hydrogen that is exhaled by the subject. By measuring breath hydrogen, the transit time of nutrients from ingestion to the terminal ileum can be estimated. No differences were seen in orocecal transit time between young (2–5 years) and senior (12–15 years) cats (Papasouliotis et al., 1998). The large individual total transit time variability observed in senior cats could be due to structural changes such as age-related atrophic degeneration (Hohn et al., 1978) which may lead to a reduction in smooth muscle activity, resulting in slower peristalsis and delayed colonic propulsion in some senior cats.

In conclusion, this study demonstrated that alterations in the rate of nutrient passage through the GI tract is unlikely to contribute to the observed decrease in apparent nutrient digestibility in ageing cats. This suggests that other factors such as decreased enzymatic secretion and/or activity, intestinal epithelial atrophy or changes in bile composition may be involved. Further studies are warranted to determine the causes of reduced nutrient digestibility in ageing cats.

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References

Clarkston, W.K., Pantano, M.M., Morley, J.E., Horowitz, M., Littlefield, JM., Burton, F.R., 1997. Evidence for the anorexia of ageing: gastrointestinal transit and hunger in healthy elderly vs. young adults. Am. J. Physiol. 272R, 243–248.

Fucci, V., Pechman, R.D., Hedlund, C.S., Venugopalan, C.S., 1995. Large bowel transit times using radiopaque markers in normal cats. J. Am. Anim. Hosp. Assoc. 35, 473–477.

Gainsborough, N., Maskrey, V.L., Nelson, M.L., Keating, J., 1993. The association of age with gastric emptying. Age Ageing 22, 37–40.

Ghoos, Y., Rutgeerts, P., Hiele, M., 1994. *CO2/H2 breath tests as clinical diagnostic tests. In: Use of Stable Isotopes in Medical Practice. Universitaire Ziekenhuizen, Leuven.

Goggin, J.M., Hoskinson, J.J., Butine, M.D., Foster, L.A., Myers, N.C., 1998. Scintigraphic assessment of gastric emptying of canned and dry diets in healthy cats. Am. J. Vet. Res. 59, 388–392.

Hohn, P., Gabbert, H., Wagner, R., 1978. Differentiation and ageing of the rat intestinal mucosa. II: Morphological, enzyme histochemical and disc electrophoretic aspects of the ageing of the small intestinal mucosa. Mech. Ageing Dev. 7, 217–226.

Holt, P.R., Dominquez, A.A., 1981. Intestinal absorption of triglyceride and vitamin D3 in aged and young rats. Dig. Dis. Sci. 26, 1109–1115.

Klein, P.D., 1991. Nutritional applications of 13C: strategic considerations. In: New Techniques in Nutritional Research. Academic Press, New York, pp. 73–94.

Madsen, J., 1992. Effects of gender, age and body mass index on gastrointestinal transit times. Dig. Dis. Sci. 37, 1548–1553.

Maes, B.D., Ghoos, Y.F., Geypens, B.J., Hiele, M.I., Rutgeerts, P.J., Vantrappen, G., 1994. Combined carbon-13-glycine/carbon-14-octanoic acid breath

test to monitor gastric emptying rates of liquids and solids. J. Nucl. Med. 35, 824–831.

Maes, B.D., Ghoos, Y.F., Geypens, B.J., Hiele, M.I., Rutgeerts, P.J., 1996. Relation between gastric emptying rate and rate of intraluminal lipolysis. Gut 38, 23–27.

Moore, J.G., Tweedy, C., Christian, P.E., Datz, F.L., 1983. Effect of age on gastric emptying of liquid–solid meals in man. Dig. Dis. Sci. 28, 340–344.

Montgomery, R.D., Haeney, M.R., Ross, I.N., Sammons, H.G., Barford, A.V., Balakrishnan, S., Mayer, P.P., Culand, L.S., Field, J., Gosling, P., 1978. The ageing gut: a study of intestinal absorption in relation to nutrition in the elderly. Q. J. Med. 47, 197–211.

Mugford, R.A., Thorne, C.J., 1980. Comparative studies of meal patterns in pet and laboratory housed dogs and cats. In: Anderson, R.S. (Ed.), Nutrition of the Dog and Cat. Pergamon Press, Oxford, pp. 3–14.

Papasouliotis, K., Sparkes, A.H., Gruffydd-Jones, T.J., Cripps, P.J., Harper, E.J., 1998. Use of the breath hydrogen test to assess the effect of age on orocecal transit time and carbohydrate assimilation in cats. Am. J. Vet. Res. 59, 1299–1302.

Peachey, S.E., Harper, E.J., Dawson, J.M., 1999. Ageing does not affect resting energy expenditure in cats. Vet. Rec. 144, 420.

Probert, C.S.J., Emmett, P.M., Heaton, K.W., 1995. Some determinants of whole-gut transit time: a population based study. Q. J. Med. 88, 311–315.

Saltzman, J.R., Russell, R.M., 1995. Gastrointestinal function and ageing. In: Morley, J.E., Glick, Z., Rubenstein, L.Z. (Eds.), Geriatric Nutrition, 2nd edition. Raven Press, New York, pp. 183–189.

Sharpe, S.J., Robinson, M.F., 1970. Intermittent and continuous faecal markers in short-term metabolic balance studies in young women. Br. J. Nutr. 24, 489–500.

Siddons, R.C., Paradine, J., Beever, D.E., Cornell, P.R., 1985. Ytterbium acetate as a particulate-phase digesta-flow marker. Br. J. Nutr. 54, 509–519.

Smits, G.J., Lefebvre, R.A., 1995. Influence of ageing on gastric emptying of liquids, small intestine transit and fecal output in rats. Exp. Gerontol. 31, 589–596.

Taylor, E.J., Adams, C., Neville, R., 1995. Some nutritional aspects of ageing in cats and dogs. Proc. Nutr. Soc. 54, 645–656.

Varga, F., 1976. Transit time changes with age in the gastrointestinal tract of the rat. Digestion 14, 319–324.

Yuasa, H., Kawanishi, K., Watanabe, J., 1995. Effects of ageing on the oral absorption of D-xylose in rats: analysis of gastrointestinal disposition. J. Pharm. Pharmacol. 47, 576–580.