Evaluation of various gastrojejunostomy tube constructs for enteral support of small animal patients

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OBJECTIVE

To evaluate the feasibility of manufacturing gastrojejunostomy tubes from jejunostomy and gastrostomy tubes that would allow for gastric and enteral feeding of and aspiration of gastric contents from small animal patients.

DESIGN

In vitro study.

SAMPLE

9 gastrojejunostomy constructs.

PROCEDURES

Commercially available gastrostomy and jejunostomy tubes were combined to create 9 constructs. Three investigators tested each construct with 4 solutions (tap water, a commercial enteral diet, and 2 canned food–water mixtures) and 3 syringe sizes for ease of injection through the gastrostomy and jejunostomy tubes and aspiration through the gastrostomy tube. Flow rates were calculated and analyzed to evaluate effects of tube diameter and syringe size for each solution.

RESULTS

The 20F/8F, 24F/8F, 28F/8F, and 28F/10F (gastrostomy tube/jejunostomy tube) constructs allowed for injection and aspiration of all solutions. The 5F jejunostomy tubes allowed only water to be injected, whereas the 8F jejunostomy tubes did not allow injection of the canned food–water mixtures. The 20F/10F construct did not allow injection or aspiration through the gastrostomy tube, whereas the 18F/8F construct allowed injection but not aspiration through the gastrostomy tube. Faster flow rates through the gastrostomy tube were associated with larger gastrostomy tube diameter, smaller jejunostomy tube diameter, and smaller syringe size. Faster flow rates through the jejunostomy tube were associated with smaller jejunostomy tube diameter.

CONCLUSIONS AND CLINICAL RELEVANCE

Results suggested that homemade gastrojejunostomy constructs would allow for administration of a variety of enteral diets. Limitations to the administration and aspiration of various enteral diets as well as patient needs should be considered before a gastrojejunostomy tube combination is chosen. (*J Am Vet Med Assoc* 2018;252:1239–1246)

With the growing availability and improving capabilities of small animal intensive care facilities, there is an increasing demand for more advanced nutritional support of veterinary patients. Feeding tubes such as J-tubes, G-tubes, and esophagostomy tubes have been commonly used in small animals.[1–14] In instances when both prepancreatic (ie, gastric) and postpancreatic (ie, jejunal) feeding is desired, having a single-access option would be ideal. In addition, when performing enteral feeding with a G-tube or J-tube, being able to measure gastric residual volume may help prevent complications such as regurgitation and aspiration pneumonia resulting from poor postoperative gastric motility.

ABBREVIATIONS

G-tube	Gastrostomy tube
J-tube	Jejunostomy tube

Several commercial options exist for placing a J-tube through a G-tube to create a single-access feeding device (ie, a gastrojejunostomy tube), but they are expensive,[a] and commercial gastrojejunostomy tube sets designed for human patients are larger than would generally be appropriate for veterinary patients. Solutions such as placement of a J-tube and a G-tube through the same body wall and gastric incisions have been suggested.[b] However, it is unknown whether this would predispose to stomal leakage if the J-tube were to be removed before the G-tube.

To our knowledge, no studies exist that assess the patency of G-tubes and J-tubes combined into gastrojejunostomy tube constructs. Therefore, the objective of the study reported here was to evaluate combinations of various sizes of commercially available J-tubes and G-tubes to determine the feasibility of manufacturing a gastrojejunostomy tube adaptable to small-breed dogs that would allow feeding through both tubes as well as aspiration of gastric contents. Our hypotheses were that all constructs would allow both feeding and aspiration through the G-tube, that a smaller syringe size would allow for a faster flow rate with both manual aspiration and fluid administration, and that both tube diameter and consistency of the enteral feeding solution would affect flow rate.

Materials and Methods

Gastrojejunostomy tube constructs

Nine gastrojejunostomy tube constructs were made with various sizes of J-tubes and G-tubes. Diameters of the J-tubes[c,d] investigated were 5F, 8F, and 10F; diameters of the G-tubes[e] investigated were 18F, 20F, 24F, and 28F. This allowed for 12 potential gastrojejunostomy tube constructs, of which the following 9 constructs (identified as G-tube diameter/J-tube diameter) were investigated: 18F/5F, 18F/8F, 20F/5F, 20F/8F, 20F/10F, 24F/8F, 24F/10F, 28F/8F, and 28F/10F.

The gastrojejunostomy tube constructs were created by cutting an access hole in the flared portion of the G-tube 1 cm from the external end and then routing the J-tube through the length of the G-tube. The access hole was made with a No. 11 scalpel blade in a linear fashion, parallel to the length of the G-tube's long axis, and just large enough to allow the J-tube to fit with minimal resistance, making sure that the J-tube was not compressed or flattened **(Figure 1; Supplementary Figure S1**, available at avmajournals.avma.org/doi/suppl/10.2460/javma.252.10.1239). The distal tip of the mushroom end of the G-tube was removed to allow the J-tube to exit the G-tube in a straight line. The J-tube entry site into the G-tube was sealed with stoma skin barrier paste[f] applied inside and outside the G-tube. Finally, a tubing adapter[g] was placed in the flared end of the G-tube, ensuring that it was placed adjacent to but not compressing the J-tube at the entry site.

Constructs were allowed to cure at room temperature (22°C [71.6°F]) and were tested for leakage 6, 12, and 24 hours after application of the stoma skin barrier paste by injection and aspiration through the G-tube of the 4 enteral feeding solutions subsequently used in the study. If a construct leaked, all stoma skin barrier paste was removed with warm saline (0.9% NaCl) solution. The construct was then allowed to dry completely, stoma paste was reapplied, and the construct was left to cure until the next testing time (eg, a construct that leaked at 6 hours was allowed to cure for 12 hours before it was tested again). Another leak test was then performed, starting with the feeding solution that had previously resulted in leakage. Constructs were labeled to identify the J-tube and G-tube diameters.

Enteral feeding solutions and syringes

Four enteral feeding solutions were chosen for testing: tap water, a commercially available enteral diet,[h] a 1:2 ratio of canned food[i] and tap water mixed in a blender (thin canned food–water mixture), and a 1:1 ratio of canned food and tap water mixed in a blender (thick canned food–water mixture). All solutions were at room temperature (22°C) at the time of administration. Three sizes of syringes[j] (20 mL, 35 mL, and 60 mL) with slip or offset tips were used.

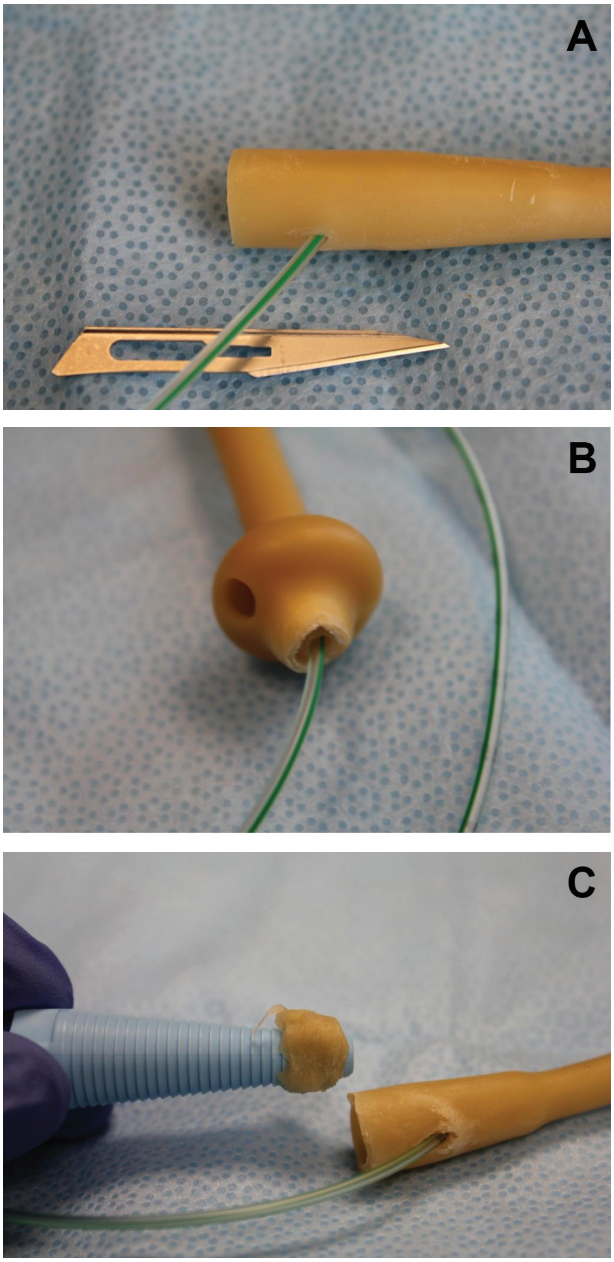

Figure 1—Photographs illustrating construction of a gastrojejunostomy tube from commercially available G- and J-tubes. A—An access hole is cut in the flared portion of the G-tube with a No. 11 scalpel blade; the hole should be just wide enough to allow easy passage of the J-tube without compressing the lumen of the J-tube. B—The distal tip of the mushroom end of the G-tube is removed to allow the J-tube to exit the G-tube in a straight line. C—Stoma skin barrier paste is applied on a tubing adapter to seal the inside of the access hole; additional paste is applied on the outside of the access hole.

Enteral feeding solution administration and aspiration

Injection through the J-tubes was assessed once by a single investigator (MR) in a single setting, with a second individual timing and observing; all 3 syringe sizes were evaluated. Both injection through and aspiration with the G-tubes were assessed with all 4 enteral feeding solutions by 3 investigators (MR, MM-L, and MK), with a second individual timing and observing; all 3 syringe sizes were evaluated. The order in which the constructs were assessed within a session was randomized by having a second person blindly pick the next construct until all constructs had been tested. For the G-tubes, aspiration was assessed first and injection was assessed second. Solutions were tested in the following order: water, enteral diet, thin canned food–water mixture, and thick canned food–water mixture. Syringes were tested in order of increasing size. All tubes were flushed with water after each test until the effluent was clear, and all feeding solutions were agitated prior to testing. Every test was performed once by every investigator.

During each test, ease of injection or aspiration of solutions was subjectively scored on a scale from 1 to 3 (1 = easy passage of the solution, without interruption; 2 = the solution did pass, but some difficulties were observed; and 3 = no passage was possible), and a flow rate (mL/min) was calculated. In addition, leakage at the interface between the J-tube and G-tube was scored as absent or present. Ease of filling and emptying the 3 sizes of syringes with the 4 enteral feeding solutions was scored on the same scale from 1 to 3 used to score ease of injection or aspiration.

Statistical analysis

Subjective assessments were recorded but not statistically analyzed. Flow rate data were modeled separately for each enteral feeding solution as a function of investigator, syringe size, and tube diameter. Because of evidence of heteroskedasticity in the residuals, flow rate data for administration through the J-tubes were log transformed, but the log-transformed data were not evaluated for normality. Differences in flow rates associated with G-tube diameter, J-tube diameter, and syringe size were assessed, with significance defined as values of $P < 0.05$ after applying the Tukey-Kramer adjustment for multiple post hoc comparisons. Because of the small sample sizes, no interaction terms were evaluated. Evaluation of residuals indicated that models fit well and that assumptions were met in analyses of flow rate during injection through and aspiration with the G-tubes. All statistical analyses were performed with standard software.[k]

Results

Leak testing and subjective assessment of filling and emptying syringes

No leakage occurred with any construct that was allowed to cure for 12 or 24 hours, but leakage did occur with 4 constructs that were allowed to cure for 6 hours. Constructs for which the stoma skin barrier paste appeared cured on its exterior surface but still felt doughy on palpation leaked during leak testing, with leakage occurring more often during injection than aspiration of the feeding solutions.

Subjectively, the 60-mL syringe was more difficult to empty and fill than the 20-mL or 35-mL syringes, especially with both canned diet–water mixtures.

J-tube injection

Subjective evaluation—Water passed easily through the 5F J-tubes (mean ± SD ease of injection score, 1.3 ± 0.52; median, 1; range, 1 to 2), but none of the other feeding solutions could be injected through the 5F J-tubes (ie, ease of administration score was 3). Water and the enteral diet passed easily through the 8F J-tubes with all 3 syringe sizes, with mean ± SD ease of administration scores of 1 ± 0 (median, 1) for water and 1.25 ± 0.45 (median, 1) for the enteral diet. Injection of the 2 canned food–water mixtures through 8F J-tubes was generally not possible. Two of the 8F J-tubes became obstructed with canned food and could not be fully cleared with water or a carbonated beverage. Injection of the thick (1:1) canned food–water mixture was only possible with the 18F/8F construct. Injection was easy for all 10F J-tubes for all 4 feeding solutions and all 3 syringe sizes (ie, ease of administration score of 1).

Flow rate of water—The overall model for flow rate of water through the J-tubes was significant ($P < 0.001$; **Table 1; Supplementary Table S1**, available at avmajournals.avma.org/doi/suppl/10.2460/javma.252.10.1239). The G-tube diameter did not significantly ($P = 0.071$) affect the J-tube water flow rate, but significant differences were found for J-tube diameter ($P < 0.001$) and syringe size ($P < 0.001$). Specifically, flow rate for the 5F J-tubes was significantly slower than flow rates for the 8F ($P < 0.001$) and 10F ($P < 0.001$) J-tubes, and flow rate for the 8F J-tubes was significantly ($P < 0.001$) slower than flow rate for the 10F J-tubes. Flow rate when using a 60-mL syringe was significantly slower than flow rate when using a 20-mL ($P < 0.001$) or 35-mL ($P < 0.001$) syringe. No significant ($P = 0.527$) difference was found in flow rate when using a 20-mL versus 35-mL syringe.

Flow rate of the enteral diet—The overall model for flow rate of the commercial enteral diet through the J-tubes was significant ($P < 0.001$). The G-tube diameter, J-tube diameter, and syringe size were all significantly ($P = 0.021$, $P < 0.001$, and $P < 0.001$, respectively) associated with flow rate. Specifically, flow rate through the J-tube was significantly ($P = 0.043$) faster for constructs with a 24F G-tube than for constructs with an 18F G-tube and significantly ($P = 0.037$) slower for constructs with a 24F G-tube than for constructs with a 28F G-tube. No other significant differences were found. Flow rate for the 10F J-tube was significantly faster than flow rates for the 5F (P

Table 1—Flow rates (mL/min) of 4 enteral feeding solutions during injection through the J-tube of 9 gastrojejunostomy tube constructs.

	Water			Enteral diet			Thin (1:2) canned food–water			Thick (1:1) canned food–water		
	Syringe size (mL)			Syringe size (mL)			Syringe size (mL)			Syringe size (mL)		
Construct	20	35	60	20	35	60	20	35	60	20	35	60
18F/5F	59	48	46	NF	NF	NF	NF	NF	NF	NF	NF	NF
18F/8F	149	241	84	64	70	17	82	101	25	37	49	15
20F/5F	78	45	22	29	NF	NF	NF	NF	NF	NF	NF	NF
20F/8F	119	101	55	52	39	22	94	NF	NF	NF	NF	NF
20F/10F	304	273	151	177	94	43	157	104	49	127	91	39
24F/8F	163	103	74	49	25	16	40	NF	NF	NF	NF	NF
24F/10F	161	155	81	57	59	40	81	90	48	87	59	29
28F/8F	132	100	68	60	34	19	NF	NF	NF	NF	NF	NF
28F/10F	314	281	142	183	103	50	114	65	65	132	97	46

Constructs are identified as G-tube diameter/J-tube diameter. Injection through the J-tubes was assessed once by a single investigator in a single setting, with a second individual timing and observing.

NF = No flow through the tube.

< 0.001) and 8F (*P* < 0.001) J-tubes. Flow rate when using a 60-mL syringe was significantly slower than flow rates when using a 20-mL (*P* < 0.001) or 35-mL (*P* < 0.001) syringe. Flow rate when using a 20-mL syringe did not differ significantly (*P* = 0.080) from flow rate when using a 35-mL syringe.

Flow rate of the thin canned food–water mixture—The overall model for flow rate of the thin (1:2) canned food–water mixture through the J-tubes was not significant (*P* = 0.162) when allowing for all effects, but the model was significant (*P* = 0.042) when reduced to only the effect of syringe size. Flow rate was significantly (*P* = 0.048) faster when using a 35-mL syringe than when using a 60-mL syringe. No other significant differences were found.

Flow rate of the thick canned food–water mixture—The overall model for flow rate of the thick (1:1) canned food–water mixture through the J-tubes was significant (*P* < 0.001). The G-tube diameter, J-tube diameter, and syringe size were all significantly (*P* < 0.001 for all 3 variables) associated with flow rate. Specifically, flow rate through the J-tube was significantly slower for constructs with an 18F G-tube than for constructs with G-tubes of any other diameter (*P* < 0.001, *P* = 0.001, and *P* = 0.003 for G-tube diameters of 20F, 24F, and 28F, respectively). Flow rate was significantly slower for the 5F J-tube than for the 8F (*P* < 0.001) or 10F (*P* < 0.001) J-tube. Flow rate when using a 60-mL syringe was significantly slower than flow rate when using a 20-mL (*P* = 0.002) or 35-mL syringe (*P* = 0.002).

G-tube injection

Investigator evaluation—For analyses of G-tube flow rates, there were significant (*P* < 0.001) investigator-to-investigator differences, but those differences were consistent across syringe size, J-tube diameter, and G-tube diameter and their interactions. That is, the size and direction of the effects of syringe size and tube diameters were not affected by the investigator, although the actual flow rate was.

Subjective evaluation—None of the solutions, including water, could be injected through the G-tube of the 20F/10F construct. Water and the commercial enteral diet could be easily injected through the G-tube for all other constructs (ease of administration score was 1). Injection of both canned food–water mixtures was also possible for constructs other than the 20F/10F construct, with a mean ease of injection score of 1.04 ± 0.2 (median, 1; range, 1 to 2) for the thin mixture and a mean ease of injection score of 1.08 ± 0.41 (median, 1; range, 1 to 3) for the thick mixture. All constructs other than the 20F/10F construct were assigned an ease of injection score of 1, except for the 18F/8F construct, which was assigned a score of 2 for the thin mixture and a score of 3 for the thick mixture.

Flow rate of water—The overall model for the flow rate of water during injection through the G-tube was significant (*P* < 0.001), with G-tube diameter, J-tube diameter, and syringe size all significantly (*P* < 0.001, *P* = 0.002, and *P* < 0.001, respectively) associated with flow rate **(Table 2; Supplementary Tables S2 and S3**, available at avmajournals.avma.org/doi/suppl/10.2460/javma.252.10.1239). Specifically, flow rate through the G-tube was significantly faster for constructs with a 5F (*P* = 0.021) or 8F (*P* = 0.004) J-tube than for constructs with a 10F J-tube. Flow rates for the 3 investigators differed significantly (*P* < 0.001) from each other. Flow rates for the 3 syringe sizes also differed significantly (*P* < 0.005 for all pairwise comparisons) from each other. Flow rate of water through the G-tube significantly increased with increasing G-tube diameter and increasing syringe size.

Flow rate of the enteral diet—The overall model for flow rate of the enteral diet during injection through

Table 2—Flow rates (mL/min) of 4 enteral feeding solutions during injection through the G-tube of 9 gastrojejunostomy tube constructs.

	Water			Enteral diet		
	Syringe size (mL)			Syringe size (mL)		
Construct	20	35	60	20	35	60
18F/5F	372 (99, 571, 444)	411 (216, 954, 63)	698 (151, 1,161, 782)	313 (67, 444, 428)	446 (129, 656, 552)	469 (128, 800, 480)
18F/8F	197 (110, 333, 148)	267 (93, 525, 182)	305 (256, 493, 166)	129 (70, 250, 66)	130 (96, 164, NF)	153 (86, 219, NF)
20F/5F	406 (218, 600, 400)	702 (364, 1,105, 636)	858 (390, 1,285, 900)	446 (135, 571, 631)	608 (241, 807, 777)	672 (322, 857, 837)
20F/8F	363 (143, 545, 400)	482 (157, 750, 538)	520 (189, 750, 620)	289 (123, 428, 315)	321 (69, 538, 355)	338 (132, 553, 330)
20F/10F	NF	NF	NF	NF	NF	NF
24F/8F	377 (157, 545, 428)	709 (396, 954, 777)	805 (569, 923, 923)	487 (231, 631, 600)	640 (330, 750, 840)	723 (365, 1,000, 818)
24F/10F	347 (241, 387, 413)	533 (255, 777, 567)	670 (314, 947, 750)	255 (52, 300, 413)	334 (59, 456, 488)	600 (78, 521, 1,200)
28F/8F	445 (333, 521, 480)	923 (650, 954, 1,166)	1,128 (715, 1,285, 1,384)	588 (307, 600, 857)	798 (538, 1,050, 807)	1,026 (533, 1,161, 1,384)
28F/10F	469 (180, 521, 705)	728 (452, 777, 954)	905 (608, 947, 1,161)	612 (248, 923, 666)	772 (403, 913, 1,000)	874 (560, 972, 1,090)

	Thin canned food–water			Thick canned food–water		
	Syringe size (mL)			Syringe size (mL)		
Construct	20	35	60	20	35	60
18F/5F	355 (100, 631, 333)	546 (214, 840, 583)	601 (184, 900, 720)	366 (118, 500, 480)	444 (202, 617, 512)	454 (151, 631, 580)
18F/8F	90 (34, 146, NF)	98 (53, 143, NF)	89 (50, 127, NF)	44 (31, 57, NF)	66 (NF, 66, NF)	NF
20F/5F	469 (87, 750, 571)	647 (342, 724, 875)	709 (180, 1,090, 857)	480 (209, 631, 600)	614 (402, 840, 600)	607 (271, 800, 750)
20F/8F	390 (79, 521, 571)	341 (122, 583, 318)	332 (95, 545, 356)	225 (74, 342, 260)	242 (75, 350, 300)	289 (86, 450, 330)
20F/10F	NF	NF	NF	NF	NF	NF
24F/8F	523 (139, 800, 631)	591 (340, 777, 656)	591 (202, 878, 692)	582 (226, 1,000, 521)	669 (345, 913, 750)	629 (329, 837, 720)
24F/10F	284 (68, 285, 500)	373 (117, 525, 477)	496 (153, 765, 571)	189 (48, 218, 300)	251 (72, 381, 300)	285 (60, 480, 313)
28F/8F	493 (133, 545, 800)	762 (228, 954, 1,105)	777 (305, 900, 1,125)	415 (203, 521, 521)	668 (283, 617, 1,105)	688 (329, 878, 857)
28F/10F	367 (80, 500, 521)	750 (231, 1,105, 913)	838 (325, 857, 1,333)	430 (224, 521, 545)	590 (153, 777, 840)	699 (376, 750, 972)

Constructs are identified as G-tube diameter/J-tube diameter. Injection through the G-tubes was assessed by 3 investigators, with a second individual timing and observing. Data represent mean (value for investigator 1, value for investigator 2, value for investigator 3).

NF = No flow through the tube.

the G-tube was significant ($P < 0.001$), and G-tube diameter, J-tube diameter, and syringe size were all significantly ($P < 0.001$, $P = 0.004$, and $P = 0.015$, respectively) associated with flow rate. Flow rate for constructs with a smaller-diameter G-tube was slower, compared with that for constructs with a larger-diameter G-tube, with flow rates for the 18F and 20F G-tubes significantly ($P < 0.008$ for all pairwise comparisons) slower than flow rates for the other patent constructs, and flow rate for the 24F G-tube significantly ($P < 0.001$) slower than flow rate for the 28F G-tube. Flow rates through the G-tube for constructs with 5F and 8F J-tubes were not significantly ($P = 0.425$) different from each other, but flow rates through the G-tube for constructs with a 5F or 8F J-tube were significantly faster, compared with flow through the G-tube for constructs with a 10F J-tube ($P = 0.007$ and $P = 0.004$, respectively). Flow rates for investigator 1 differed significantly ($P < 0.001$) from those for investigators 2 and 3, but flow rates for investigators 2 and 3 did not differ significantly ($P = 0.432$). Flow rate for injection through the G-tube was significantly slower when using the 20-mL syringe than when using the 60-mL syringe ($P = 0.012$), but not when using the 35-mL syringe ($P = 0.144$). Flow rates when using the 35-mL and 60-mL syringes did not differ significantly ($P = 0.410$).

Flow rate of the thin canned food–water mixture—The overall model for flow rate of the thin canned food–water mixture during injection through the G-tube was significant ($P < 0.001$), with G-tube diameter, J-tube diameter, and syringe size all significantly ($P < 0.001$) associated with flow rate. Flow rates for the 24F and 28F G-tubes were significantly faster than flow rate for the 18F and 20F G-tubes. Flow rate through the G-tube for constructs with a 5F or 8F J-tube was significantly faster, compared with flow rate through the G-tube for similar constructs with a 10F J-tube ($P = 0.010$ and $P = 0.007$, respectively), but there was no significant ($P = 0.415$) difference in flow rates for constructs with 5F versus 8F J-tubes. Flow rates for investigator 1 differed significantly from those for investigators 2 and 3 ($P < 0.001$), but flow rates for investigators 2 and 3 did not differ significantly ($P = 0.643$). Flow rate for injection through the G-tube was significantly faster when using the 35-mL and 60-mL syringes than when using the 20-mL syringe ($P = 0.045$ and $P < 0.001$, respectively), but flow rates for the 60-mL and 35-mL syringes did not differ significantly ($P = 0.213$).

Flow rate of the thick canned food–water mixture—The overall model for flow rate of the thick canned food–water mixture during injection through the G-tube was significant ($P = 0.001$), with G-tube diameter, J-tube diameter, and syringe size all significantly ($P < 0.001$) associated with flow rate. Flow rates for the 24F and 28F G-tubes were significantly faster than flow rates for the 18F and 20F G-tubes ($P < 0.007$ for all pairwise comparisons). Flow rate through the G-tube for constructs with a 10F J-tube was significantly slower than flow rate through the G-tube for constructs with a 5F or 8F J-tube ($P = 0.025$ and $P = 0.038$, respectively), but no significant ($P = 0.264$) difference was found for constructs with a 5F versus 8F J-tube. Flow rates for investigator 1 differed significantly from those for investigators 2 and 3 ($P < 0.001$), but flow rates for investigators 2 and 3 did not differ significantly ($P = 0.846$). Flow rate through the G-tube when using the 20-mL syringe differed significantly from that for the 60-mL syringe ($P = 0.002$), but not that for the 35-mL syringe ($P = 0.090$); flow rates for the 35-mL and 60-mL syringes did not differ significantly ($P = 0.329$).

G-tube aspiration

Subjective evaluation—None of the solutions, including water, could be aspirated through the G-tube of the 20F/10F construct. Subjectively, aspiration of the enteral diet through the G-tube of the 18F/8F construct was difficult, as was aspiration of both canned food–water mixtures through the G-tube of the 20F/8F construct, especially with the 60-mL syringe. Median ease of aspiration scores for all 4 fluid types was 1; mean ± SD ease of aspiration score was 1.08 ± 0.4 (range, 1 to 3) for water, 1.18 ± 0.49 (range, 1 to 3) for the enteral diet, 1.09 ± 0.3 (range, 1 to 2) for the thin canned food–water mixture, and 1.24 ± 0.54 (range, 1 to 3) for the thick canned food–water dilution.

Flow rate of water—The overall model for flow rate of water during aspiration through the G-tube was significant ($P < 0.001$), but only J-tube diameter was significantly associated with flow rate **(Table 3; Supplementary Tables S4 and S5**, available at avmajournals.avma.org/doi/suppl/10.2460/javma.252.10.1239). The residuals indicated that the model fit well and the assumptions were met. Flow rate during aspiration through the G-tube of the 28F/8F construct was significantly faster than flow rate for all other patent constructs, whereas flow rate with the 18F/8F construct was significantly slower than flow rate for all other patent constructs ($P < 0.001$ for all pairwise comparisons). Flow rate for investigator 3 was significantly faster than flow rates for investigators 1 and 2 ($P < 0.001$ and $P = 0.001$, respectively), but flow rates for investigators 1 and 2 did not differ significantly ($P = 0.364$). Flow rates for all 3 syringe sizes differed significantly from each other ($P < 0.033$ for all pairwise comparisons).

Flow rate of the enteral diet—The overall model for flow rate of the enteral diet during aspiration through the G-tube was significant ($P < 0.001$), with G-tube diameter, J-tube diameter, and syringe size all significantly ($P < 0.001$ for all 3 factors) associated with flow rate. Flow rate through the G-tube for the 18F/8F construct was significantly slower than flow rate for all other constructs ($P < 0.012$ for all comparisons). Flow rate when using the 20-mL syringe differed significantly from flow rates when using the other 2 syringe sizes ($P < 0.001$), but flow rates for the 35-mL and 60-mL syringes did not differ significantly ($P = 0.358$). Flow rates differed significantly ($P < 0.033$ for all pairwise comparisons) among the 3 investigators.

Table 3—Flow rates (mL/min) of 4 enteral feeding solutions during aspiration through the G-tube of 9 gastrojejunostomy tube constructs.

	Water			Enteral diet		
	Syringe size (mL)			Syringe size (mL)		
Construct	20	35	60	20	35	60
18F/5F	255 (190, 187, 387)	501 (446, 381, 677)	642 (450, 620, 857)	233 (153, 315, 230)	323 (207, 428, 333)	383 (188, 571, 391)
18F/8F	72 (63, 84, 70)	148 (173, 148, 122)	139 (159, 127, 131)	32 (18, 57, 20)	131 (NF, 131, NF)	NF
20F/5F	321 (218, 266, 480)	632 (403, 538, 954)	722 (461, 734, 972)	286 (148, 324, 387)	469 (323, 428, 656)	550 (310, 620, 720)
20F/8F	243 (230, 244, 255)	377 (388, 362, 381)	517 (439, 480, 631)	142 (141, 184, 100)	155 (187, 166, 112)	165 (157, 197, 142)
20F/10F	NF	NF	NF	NF	NF	NF
24F/8F	362 (244, 363, 480)	658 (437, 538, 1,000)	570 (562, 455, 692)	296 (235, 240, 413)	470 (355, 488, 567)	534 (330, 580, 692)
24F/10F	288 (315, 250, 300)	447 (446, 396, 500)	599 (444, 571, 782)	151 (123, 218, 112)	220 (175, 304, 181)	349 (155, 705, 188)
28F/8F	302 (222, 500, 184)	629 (488, 700, 700)	838 (590, 923, 1,000)	263 (151, 315, 324)	478 (304, 512, 617)	667 (349, 705, 947)
28F/10F	329 (342, 164, 480)	555 (480, 411, 777)	787 (600, 734, 1,028)	262 (190, 352, 244)	509 (375, 600, 552)	555 (473, 705, 486)
	Thin canned food–water			Thick canned food–water		
	Syringe size (mL)			Syringe size (mL)		
Construct	20	35	60	20	35	60
18F/5F	287 (307, 315, 240)	361 (280, 466, 338)	398 (220, 545, 428)	205 (164, 255, 196)	291 (157, 437, 280)	388 (NF, 461, 315)
18F/8F	NF	NF	NF	NF	NF	NF
20F/5F	360 (235, 400, 444)	485 (323, 477, 656)	436 (236, 236, 837)	279 (179, 315, 342)	477 (344, 488, 600)	430 (241, 529, 521)
20F/8F	176 (193, 206, 129)	144 (128, 165, 139)	95 (81, 93, 110)	72 (47, 88, 81)	66 (48, 99, 51)	53 (45, 82, 32)
20F/10F	NF	NF	NF	NF	NF	NF
24F/8F	379 (363, 375, 400)	485 (403, 396, 656)	555 (493, 493, 679)	260 (240, 226, 315)	463 (344, 428, 617)	499 (439, 529, 529)
24F/10F	206 (222, 218, 179)	184 (137, 235, 181)	131 (122, 122, 148)	77 (56, 127, 48)	72 (54, 112, 50)	64 (48, 116, 33)
28F/8F	378 (200, 413, 521)	569 (283, 583, 840)	465 (279, 279, 837)	258 (162, 363, 250)	512 (262, 617, 656)	618 (315, 818, 720)
28F/10F	322 (240, 363, 363)	488 (375, 488, 600)	481 (375, 375, 692)	278 (196, 461, 176)	403 (308, 567, 333)	506 (318, 580, 620)

Constructs are identified as G-tube diameter/J-tube diameter. Aspiration through the G-tubes was assessed by 3 investigators, with a second individual timing and observing. Data represent mean (value for investigator 1, value for investigator 2, value for investigator 3).

NF = No flow through the tube.

Flow rate of the thin canned food–water mixture— The overall model for flow rate of the thin canned food–water mixture during aspiration through the G-tube was significant ($P < 0.001$), with G-tube diameter and J-tube diameter significantly ($P < 0.001$) associated with flow rate. Flow rates for investigator 1 differed significantly from flow rates for investigators 2 and 3 ($P < 0.001$ for both comparisons), but flow rates for investigators 2 and 3 did not differ significantly ($P = 0.962$). Syringe size was not significantly ($P = 0.056$) associated with flow rate during aspiration.

Flow rate of the thick canned food–water mixture— The overall model for flow rate of the thick canned food–water mixture during aspiration through the G-tube was significant ($P < 0.001$), with G-tube diameter, J-tube diameter, and syringe size all significantly ($P < 0.001$) associated with flow rate. Flow rates obtained when using the 3 different syringe sizes differed significantly ($P < 0.001$), and flow rates for the 3 investigators differed significantly ($P < 0.002$).

Discussion

In the present study, several gastrojejunostomy tube constructs—created by inserting a J-tube through a G-tube—were found to be functional for feeding through both the J-tube and G-tube while allowing aspiration of feeding solution through the G-tube. Larger-diameter G-tubes and smaller-diameter J-tubes were associated with faster flow rates through the G-tubes. Larger-diameter J-tubes were associated with faster flow rates through the J-tubes.

The rationale for the present study was to assess patency of a variety of gastrojejunostomy tubes in the hands of several operators. All patent G-tubes allowed flow at a rate faster than the typically desired clinical feeding rate (ie, a bolus feeding of a meal over 30 minutes).[15] In the present study, we used flow rate as a measure of the speed and ease with which the enteral feeding solutions could be injected or aspirated. Although not clinically applicable, all investigators were asked to inject or aspirate the solutions as fast as possible to allow comparisons between investigators. Although we did find significant differences between individual constructs, all flow rates were faster than what would be clinically appropriate. Therefore, rates of administration that were achieved in the present study are not applicable to clinical situations. Using an infusion pump would have provided us with more standardized flow rates but would not have mimicked the clinical situation or provided information on ease of use.

Three syringe sizes were evaluated as part of the present study to assess whether a larger syringe allowed for faster feeding and aspiration. Generally, syringe size was not significantly associated with flow rate. Subjectively, using the 60-mL syringe was more difficult, but this could have been somewhat dependent on hand size. All 3 investigators had fairly small hands (2 wore size 6 1/2 surgical gloves and 1 wore size 7). Hand strength of the investigators was not tested, but could have created an interinvestigator difference as well. While assessing rate of aspiration through the G-tubes, negative pressure was obtained with some constructs for which the diameters of the G-tube and J-tube differed less, forcing the investigator to temporarily adjust or release the negative pressure, after which flow resumed.

Only water could be injected through the 5F J-tubes used in the present study, making this an ineffective option for postpancreatic (ie, jejunal) feeding. Thus, a larger-diameter J-tube should be used for smaller patients or only a very dilute enteral nutrition or a parenteral nutrition solution should be used if a 5F J-tube is needed. No solution could be injected or aspirated through the G-tube of the 20F/10F construct. The outer diameter of the J-tube was similar in size to the inner diameter of the 20F G-tube, making this combination inappropriate for use.

In the present study, we noted that the stoma paste needed to cure sufficiently to provide a long-lasting seal. No leakage occurred when constructs were allowed to cure for 12 or 24 hours. If a gastrojejunostomy tube is inserted in a patient before the stoma paste has completely cured, it may be necessary to occlude the G-tube lumen with a clamp for the first 12 hours to prevent gastric fluid from reaching the stoma paste and to assess the consistency of the stoma paste prior to use. However, feeding through the J-tube should be safe even before the stoma paste has completely cured, although this would need to be in bolus form so the G-tube could be occluded.

Several commercial diet choices are currently available for small animal veterinary patients. We chose to evaluate only 1 commercial enteral diet and only 2 consistencies of a commercial canned diet mixed with water. Although the enteral solutions evaluated in the present study may not be used clinically for J-tube feeding, they allowed assessment of the feasibility of injecting fluids of various consistencies through the J-tube. For patients with delayed gastric emptying, as is often the case in patients requiring a gastrojejunostomy tube, aspiration often occurs following feeding. We have used the constructs evaluated in the present study clinically in small patients (< 5 kg [11 lb]) prior to and after this study. The J-tubes were easy to remove, and the constructs did allow simultaneous aspiration of the G-tube while providing enteral feeding through the J-tube. The constructs used in the present study cost approximately $45 to $50/construct (including the tube kit, stoma skin barrier paste, and surgical blade) at the time, which we suggest is more economical than current commercially available gastrojejunostomy tube constructs ($109).

Additional combinations (18F/10F, 24F/5F, and 28F/5F) of tube constructs could have been evaluated in the present study. However, assembly of an 18F/10F construct was impossible because of the size of the 10F J-tube, compared with the inner diameter of the 18F G-tube, and the 24F/5F and 28F/5F constructs were not tested because patients in which a

24F or 28F G-tube would be placed would also accommodate an 8F or 10F J-tube, making these constructs less clinically relevant. Although there are potential limitations associated with using homemade constructs, we believe that this gastrojejunostomy tube design provides a solution for small animal patients, enabling placement of a gastrojejunostomy tube during surgery without having to stock more expensive specialty feeding tubes. In the present study, the following constructs performed best: 20F/8F, 24F/8F, 28F/8F, and 28F/10F. Use of these constructs would allow for various options, depending on the preferred G-tube size.

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Footnotes

a. MILA International Inc, Erlanger, Ky.
b. Mathews KG, College of Veterinary Medicine, North Carolina State University, Raleigh, NC: Personal communication, 2014.
c. Argyle feeding tube (5F × 36 in and 10F × 42 in), Covidien LLC, Mansfield, Mass.
d. Kangaroo (8F × 42 in), Covidien LLC, Mansfield, Mass.
e. Bard urethral catheter, Bard Ltd, CR Bard Inc, Covington, Ga.
f. Stomahesive, ConvaTec Inc, Skillman, NJ.
g. SurgiVet, Smiths Medical ASD Inc, Saint Paul, Minn.
h. Vivonex, Nestlé HealthCare Nutrition Inc, Florham Park, NJ.
i. Hill's Prescription Diet a/d, Canine/Feline Critical Care, Hill's Pet Nutrition Inc, Topeka, Kan.
j. Covidien LLC, Mansfield, Mass.
k. SAS, version 9.3, SAS Institute Inc, Cary, NC.

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