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RETROSPECTIVE STUDY

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Audit of the provision of nutritional support to mechanically ventilated dogs and cats

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Abstract

Objectives: To evaluate the use of enteral and parenteral nutrition in a population of mechanically ventilated cats and dogs, identify factors associated with implementation of nutrition, and assess the frequency of nutritional support within 72 hours of absent caloric intake.

Design: Retrospective, single-center audit from June 2013 to June 2016.

Setting: ICU of a veterinary university teaching hospital.

Animals: Fifty-eight animals (50 dogs, 8 cats) that underwent mechanical ventilation for ≥6 hours with complete medical records.

Interventions: None.

Measurements and Main Results: Data collected included nutritional provision, time to initiation of nutrition, period of absent caloric intake, percentage of caloric intake obtained, and possible factors contributing to the delay or failure to implement nutrition. Thirty-one percent of patients (dogs 16/50, 32%; cats 2/8, 25%) received nutritional support during mechanical ventilation with all but 2 dogs receiving parenteral nutrition. Of those patients that did not receive nutrition (dogs 34/50, 68%; cats 6/8, 75%), documented contraindications or notations within the medical record for its omission were present in 16 of 34 dogs (47%) and 4 of 6 cats (66.7%). Thirteen animals (11 dogs, 2 cats) had >72 hours of absent caloric intake with only a small number of these receiving nutrition (dogs 4/11, 36.4%; cats 0/2, 0%).

Conclusions: Only 18 of 58 (31%) mechanically ventilated dogs and cats at our institution received nutritional support, and the majority of these were fed parenterally (16/18, 88.9%). For animals that did not receive nutrition, there was no clear reason for its absence in many cases. Animals with absent caloric intake >72 hours had poor implementation of nutritional support in contrast to current guidelines. A repeat audit after implementing changes to institutional protocols for nutritional provision is warranted to assess the impact on morbidity and mortality.

Abbreviations: BCS, body condition score; CRI, continuous rate infusion; EN, enteral nutrition; MV, mechanical ventilation; NNS, no nutritional support; PN, parenteral nutrition; RER, resting energy requirements; VAP, ventilator-associated pneumonia.

KEYWORDS
canine, critical illness, enteral nutrition, feline, parenteral nutrition

1 | INTRODUCTION

Clinical audits can be a valuable tool for assessing provided care against assumed or published standards and guidelines.[1] Audits of topics relating to nutrition are common in people and can drive improvements in clinical practice.[2–7] At present, there are no specific guidelines for nutritional support in dogs and cats undergoing mechanical ventilation (MV), although for general small animal populations several sources recommend the provision of nutritional support when the daily resting energy requirement (RER) has not been achieved for a period of 3 or more days.[8–10]

In people with severe respiratory disease, poor nutritional state causes decreased respiratory drive to hypoxemia,[11] reduced surfactant production,[12] respiratory muscle catabolism and weakness resulting in difficulty weaning from MV,[13] and altered respiratory defense mechanisms.[14] Excessive nutrition is also harmful, with excessive carbohydrate administration resulting in hypercarbia and prolonged dependence on MV in critically ill people.[15,16] The appropriate provision of nutritional support in critically ill ventilated people is proven to reduce morbidity, mortality, and length of hospitalization, and to increase ventilator-free days.[17–21] Timing and modality of nutritional support are also important: in people, enteral nutrition (EN) is preferred and instituting EN within 48 hours of MV has been documented to reduce morbidity and mortality in numerous studies and meta-analyses.[13,20,22]

To the authors' knowledge, there are no studies evaluating the provision of nutrition to critically ill mechanically ventilated cats and dogs; thus, the aim of this investigation was to perform a clinical audit of this population at our institution. Additional aims included to elucidate factors that may contribute to absent or delayed nutrition and to assess the rate of implementation of nutritional support within 72 hours of known absent caloric intake.

2 | METHODS

2.1 | Patient population

Electronic patient records at the Queen Mother Hospital for Animals, Royal Veterinary College were searched for cats and dogs that underwent MV between June 1, 2013 and June 30, 2016. Cases had their electronic and paper records analyzed for pertinent details of case management. Patients were included if they were confirmed to have received MV for ≥6 hours during the audit period. Selection of patients that were ventilated for ≥6 hours was performed in order to exclude patients that were, for example, only ventilated until clients could be present for euthanasia, and those animals that were euthanized or died prior to being appropriately instrumented (eg, without appropriate vascular access for parenteral nutrition [PN]). Patients were excluded from the audit if the medical records could not be retrieved or contained insufficient data to assess their nutritional provision. Ethical approval as required by the authors' institution was granted by the Social Science Research Ethical Review Board of the Royal Veterinary College (URN SR2017-1187).

2.2 | Data collection

General patient data recorded included species, breed, age at the time of MV, body weight, diagnosis, indication for MV, and survival to discharge. Nutritional data recorded included the body condition score (BCS; 9-point scale), nutritional modality (enteral/parenteral/none), product used, duration and rate of infusion (for PN), continuous rate infusion (CRI) or bolus feeding (for EN), time period prior to MV without caloric intake (including the period prior to hospital admission), and the length of time during MV without nutritional provision. In cases where the time period without caloric intake prior to MV could not be determined with precision (such as an inability of the owner to remember the exact time of feeding), the nearest 12-hour period with known absence of caloric intake was used. In cases where the period of absent caloric intake prior to hospitalization was unknown, it was assumed animals had a no period of absent intake prior to hospitalization. In cases in which there was either delayed or absent nutritional provision, contributing factors as noted within the medical record were documented, including any statements citing why nutrition was being withheld at that time.

Contraindications to EN were defined to include hypotensive episodes (defined as a systolic arterial blood pressure <90 mm Hg or a mean arterial blood pressure <60 mm Hg); localized trauma or recent surgery at the proposed feeding tube site; and gastrointestinal problems including vomiting, regurgitation, megaesophagus, ileus, gastrointestinal obstruction, and maldigestive/malabsorptive syndromes. Contraindications to parenteral feeding were defined to include the lack of appropriate dedicated vascular access (defined as the absence of a dedicated single lumen peripheral or central venous catheter, or the absence of a dedicated port of a multi-lumen central venous catheter), uncontrolled diabetes mellitus, and hypervolemia. The provision of calories was compared to the animal's RER using the following formula[23]: $RER = 70 \times (\text{body weight [kg]})^{0.75}$. The body weight used for this formula was the most recent body weight for each animal during the period in which nutrition was provided.

Indications for MV were defined as either hypoxemia (Pa_{O_2} < 60 mm Hg or Sp_{O_2} < 90% despite oxygen supplementation, or $Pa_{O_2}/Fi_{O_2} \leq 200$), hypoventilation ($P_{CO_2}$ > 60 mm Hg), upper respiratory tract obstruction, subjective clinician assessment of respiratory fatigue, postcardiopulmonary arrest, or a combination there of.

The level of instrumentation with devices required for nutritional provision (central venous catheterization, long-stay venous catheterization, or feeding tube placement) was recorded. Complications experienced during MV including ventilator-associated pneumonia (VAP) and regurgitation were also recorded. VAP was diagnosed if an initial bronchoalveolar lavage was aseptic but repeat airway sampling following >48 hours of MV then documented the presence of bacteria, or if the initial sample was septic but subsequent airway sampling >48 hours after the onset of ventilation documented growth of a different organism. Regurgitation had to be witnessed and documented to be included. Any recorded mechanical or septic complications attributable to PN were also recorded. Metabolic complications were not assessed due to lack of standardized monitoring in patients receiving PN.

2.3 | Statistical analysis

Data distribution was assessed for normality using the Shapiro–Wilk test. Normally distributed data were reported as mean and standard deviation (SD) and nonnormally distributed data as median and range.

3 | RESULTS

Eighty-six patients were identified for possible inclusion into the audit (78 dogs, 8 cats). Eighteen dogs were excluded because insufficient records were available for appropriate data collection and 10 dogs were excluded because the duration of MV was <6 hours. Following exclusions, 50 dogs and 8 cats were included in the audit population (Figure 1).

3.1 | Population

3.1.1 | Dogs

There were 19 female (10 neutered, 9 entire) and 31 male (17 neutered, 14 entire) dogs. Breeds included French Bulldog (n = 6), English Bulldog (n = 5), crossbreeds (n = 5), Golden Retriever (n = 3), Labrador Retriever (n = 3), Border Collie (n = 2), Cavalier King Charles Spaniel (n = 2), Weimaraner (n = 2), and 1 dog each of 22 other breeds. The median body weight of the dogs was 14.5 kg (range = 1.7–60.5 kg) and median age was 3.2 years (range = 0.2–13.8 y). Clinical diagnoses and comorbidities for each patient are documented in Appendix A.

3.1.2 | Cats

There were 6 female (5 neutered, 1 entire) and 2 male neutered cats. Breeds included Domestic Shorthair (n = 6), Domestic Longhair (n = 1), and British Shorthair (n = 1). Cats had a mean (SD) weight of 3.8 (± 1.2) kg, and mean (SD) age of 6.7 (± 3.3) years. Clinical diagnoses and comorbidities for each patient are documented in Appendix B.

3.2 | Ventilation: Indications, duration, and outcome

3.2.1 | Dogs

Indications for initiating MV were hypoxemia (28/50, 56%), hypoventilation (7/50, 14%), respiratory fatigue (5/50, 10%), upper respiratory tract obstruction (5/50, 10%), and a combination of hypoxemia, hypoventilation, and respiratory fatigue (5/50, 10%). Median duration of MV was 27.5 hours (range = 7–169 h). Sixteen dogs (16/50, 32%) survived to discharge.

3.2.2 | Cats

Indications for initiating MV were postcardiopulmonary arrest (4/8, 50%), hypoventilation (3/8, 37.5%), and a combination of hypoxemia, hypoventilation, and fatigue (1/8, 12.5%). Median duration of MV was 21 hours (range = 8–208 h). Two cats (2/8, 25%) survived to discharge.

3.3 | Nutritional assessment

3.3.1 | Dogs

Sixteen dogs (16/50, 32%) received nutritional support during MV (EN: 2/50, 4%; PN: 14/50, 28%). Thirty-four dogs (34/50, 68%) received no nutritional support (NNS) during MV. Nine dogs (9/50, 18%) had a recorded BCS with a median of 4 (range = 3–9). Dogs receiving any form of nutrition had a mean (SD) time from starting MV to nutritional support of 30.1 (± 23.4) hours. In the 2 dogs receiving EN, the time from starting MV to nutritional support was 45 and 74 hours, respectively. In dogs receiving PN, the median time from starting MV to nutritional support was 20 hours (range = 0–98 h). Sixteen dogs (16/50, 32%) survived to discharge, out of which 5 received PN (5/16, 31.2%), whereas the remaining dogs (11/16, 68.8%) received NNS. No dog that survived to discharge received EN.

Ten dogs had an unknown period of absent caloric intake prior to hospitalization (PN: n = 4; NNS: n = 6). The duration of absent caloric intake prior to MV was known for 40 dogs with a median duration of 24 hours (range = 4–48 h). Prior to MV, no dog had a period of absent caloric intake >72 hours. Of the 16 dogs that were fed, 12 received nutrition before (12/16, 75%; PN: n = 12) and 4 after (4/16, 25%; PN: n = 2; EN n = 2) 72 hours of absent caloric intake had elapsed (<72 h: mean [SD] = 39.23 [± 10.6] h; >72 h: median = 95.5 h, range = 75–98 h). In dogs with NNS (n = 34), 18 died or were euthanized and 9 weaned from MV before 72 hours elapsed (mean [SD]

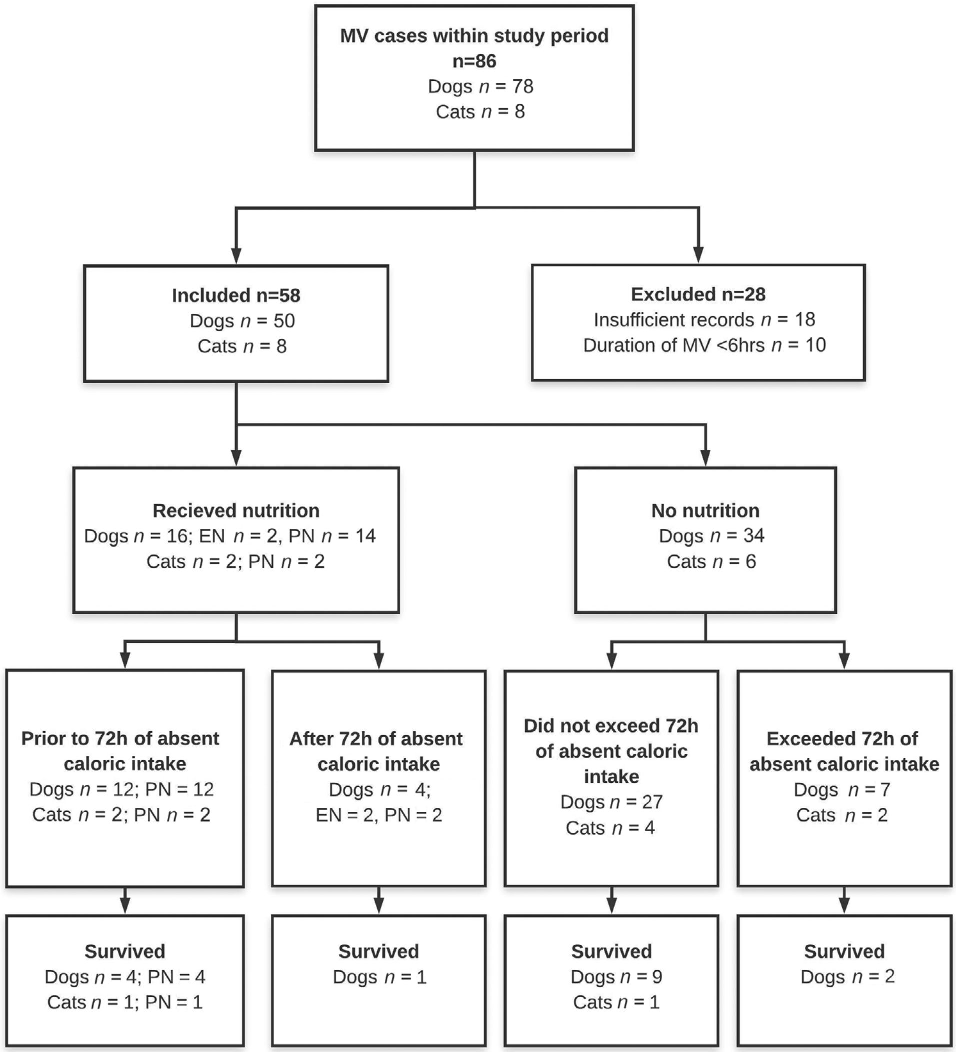

FIGURE 1 Flowchart outlining excluded patients, the provision of nutrition, the timeframe of its provision, and survival within the audit Abbreviations EN, enteral nutrition; MV, mechanical ventilation; PN, parenteral nutrition

periods of absent caloric intake of 35.7 [± 8.1] and 39.6 [± 9.1] h, respectively). Seven dogs with NNS exceeded 72 hours with absent caloric intake; of these dogs, 2 survived (90 and 97 h of absent caloric intake) and 5 died or were euthanized (median = 86 h, range = 74–95 h). The number of dogs surviving from each category is displayed in Figure 1.

3.3.2 | Cats

Two cats (2/8, 25%) received nutritional support (PN) during MV. Six cats (6/8, 75%) received NNS. One cat had a BCS of 5/9, whereas no other cat had a BCS recorded. The duration of absent caloric intake prior to ventilation was available for 5 cats with a mean (SD) duration of 48.4 (± 24.8) hours. Prior to MV, 2 of 8 cats (25%) had a period of absent caloric intake >72 hours; neither of these cats received nutritional support during their period of ventilation and neither survived to discharge. When the periods prior to and during ventilation without any caloric intake were combined, only these 2 cats exceeded 72 hours with no caloric intake. Cats receiving nutritional support had a mean (SD) time from starting MV to nutritional support of 4.5 (± 0.7) hours. Of the 2 of 8 (25%) cats who survived to discharge, 1 received nutritional support (PN).

Of the 2 cats that were fed, both received nutrition before 72 hours of absent caloric intake had elapsed (PN: $n = 2$; 4 and 19 h of absent caloric intake). In cats with NNS ($n = 6$), 3 died or were euthanized (mean ± SD = 50.5 ± 18.5 h) and 1 was weaned from MV before 72 hours elapsed (59 h). Two NNS cats exceeded 72 hours of absent caloric intake with periods of 86.5 and 88 hours. In total, 2 cats survived to discharge (PN: $n = 1$; NNS: $n = 1$) without exceeding 72 hours of absent caloric intake. The number of cats surviving from each category is displayed in Figure 1.

3.4 | Parenteral nutrition

3.4.1 | Dogs

PN was provided in 14 of 50 (28%) dogs. Twenty-five dogs had jugular central venous catheters, 3 dogs had long-stay lateral saphenous catheters, and 1 dog had both types of catheters. Thirteen dogs received a 3-in-1, ready-made PN product[a] containing lipids, amino acids, and glucose, and 1 dog received a 20% lipid emulsion[b] for treatment of an ingested toxin. Four dogs supported with PN received a variable rate infusion (escalating rate [$n = 3$], de-escalating rate [$n = 1$]) and 10 dogs received a CRI for the entire duration of their PN (1 ml/kg/h [$n = 1$], 2 ml/kg/h [n = 8], 15 ml/kg/h [$n = 1$]). Dogs receiving a 2 ml/kg/h CRI of PN achieved 81% (SD ± 22%) of their daily RER. Those on variable rate infusions (when averaged for the duration of the PN infusion) achieved 64.4% (SD ± 8.3%) of their daily RER. The dog who received a 20% lipid emulsion infusion at a rate of 15 ml/kg/h received 22.1% of its daily RER within the 20-minute infusion. In all cases other than the dog treated with intravenous lipid emulsion therapy, PN was continued until the patient died, was euthanized, or was weaned from MV with a median duration of 34.5 hours (range = 16–145 h).

3.4.2 | Cats

PN was provided in 2 of 8 (25%) cats. Five cats (5/8, 62.5%) had jugular central venous catheters. Both cats receiving PN had variable rate infusions and when averaged for the duration of the PN infusion received a mean (SD) of 45.3% (± 12.2%) of daily RER. In these cats, PN was continued until the patient was either euthanized or weaned from MV with durations of 203 and 14 hours, respectively.

3.5 | Enteral nutrition

EN was provided in 2 of 50 (4%) dogs and in no cats. Seven dogs (7/50, 14%) had nasogastric tubes. No other enteral feeding devices were used, and no cat had an enteral feeding device. Dogs on EN received a mean (SD) 25.9% (± 14.1%) of their daily RER during feeding. Both dogs that received EN did so as a CRI and both were fed with 1 each of a commercially available liquid diet.[c,d] In both dogs, EN was continued until they suffered cardiopulmonary arrest following 7 and 17 hours of feeding, respectively.

[a] Kabiven Peripheral 900 kcal/5 gN, Fresenius Kabi AB., Uppsala, Sweden.
[b] Intralipid 20% (w/v), Fresenius Kabi Limited, Runcorn, UK.
[c] Convalescence Support Instant Diet Canine Feline, Royal Canin SAS., Gard, France.
[d] EnteralCare KC Canine, PetAg Inc., Hampshire, IL.

3.6 | Factors contributing to absent or delayed nutrition

3.6.1 | Dogs

Nutrition was initiated prior to 72 hours of absent caloric intake occurring in 12 dogs (PN: $n = 12$) and following >72 hours of absent caloric intake in 4 dogs (EN: $n = 2$; PN: $n = 2$). Both dogs that received EN had long-stay vascular catheters in place and did not have a contraindication to PN; both had EN provided within 2 hours of nasogastric tube placement. Both dogs that received PN following >72 hours of absent caloric intake did so within hours of having a long-stay catheter placed. In half of all dogs that received PN (7/14, 50%), there was a temporal association with the placement of an appropriate device and PN beginning immediately after placement. For NNS dogs (34/50, 68%), a contraindication or citation within the record for the lack of nutrition could not be identified in 18 of 34 (52.9%) cases. For the remaining 16 dogs that did not receive nutritional support, 9 dogs (56.3%) had the following defined contraindications to either EN or PN: gastrointestinal disease (5/9, 55.6%), hypotension (2/9, 22.2%), or lack of appropriate vascular access (2/9, 22.2%). Of these 9 dogs, no dog had a contraindication to both EN and PN, and 1 dog with ileus had appropriate vascular access present but was not provided with PN. The final 7 of 16 (43.7%) dogs had citations within their medical records documenting why nutrition was not provided and these included normal nutritional intake immediately prior to the onset of MV (5/7, 71.4%), expected short duration MV to confirm a grave prognosis prior to euthanasia (1/7, 14.3%), and the desire to avoid PN due to a recently placed transvenous pacemaker (1/7, 14.3%). This final dog did not have a documented contraindication to EN.

3.6.2 | Cats

Nutrition (PN) was initiated prior to 72 hours of absent caloric intake in 2 cats; no other cat received nutrition. For those 6 of 8 (75%) cats with NNS, 4 of 6 (66.7%) had defined contraindications to either PN or both PN and EN: lack of appropriate vascular access (3/4, 75%) and uncontrolled diabetes along with recent surgery at the proposed tube placement site (1/4, 25%). Only this final cat had contraindications to both PN and EN and in the remaining cats (2/8, 25%), there was no obvious contraindication to either modality of nutritional provision and no notation in the medical record outlining why it had been withheld.

3.7 | Complications

Seven dogs and 1 cat developed VAP; pure growth of *Escherichia coli* was cultured from the cat, with 6 of 7 (85.7%) dogs having mixed growth of organisms with the most common being *E. coli* ($n = 3$), *Pseudomonas aeruginosa* ($n = 3$), *Enterococcus faecalis* ($n = 2$), and 1 each of *Staphylococcus pseudintermedius*, *Enterococcus faecium*, *Streptococcus* *canis*, and *Enterobacter*, *Clostridia*, and *Bacteroides* spp. that were not further identified. Microbiology results for the final dog were not available. Six dogs were noted to regurgitate during MV; however, none of these patients received EN. In dogs receiving EN, the incidences of regurgitation and VAP were both 0 per patient per day. In dogs receiving PN, these incidences were 0.08 and 0.1 per patient per day, respectively. In dogs receiving NNS, these incidences were 0.08 and 0.1 per patient per day, respectively. No cat received EN; the incidence of regurgitation or VAP was 0 and 0.11 per patient per day, respectively, for those receiving PN, and 0 per patient per day for both for those receiving NNS. No patient receiving PN had a documented mechanical or septic complication recorded.

4 | DISCUSSION

In this audit, the number of animals receiving nutritional support at any timepoint was low (dogs 16/50, 32%; cats 2/8, 25%). The number of animals that received nutrition before 72 hours of absent caloric intake had occurred was also low (dogs 12/50, 24%; cats 2/8, 25%). Many animals who exceeded 72 hours without nutrition failed to be administered nutrition at any time (dogs 7/11, 63.6%; cats 2/2, 100%). The majority of animals that did receive nutrition were administered PN (16/18, 88.9%) in contrast to the recommended modality of nutritional support in critically ill ventilated human patients.[24]

The reasons why many patients had absent, or a marked delay in initiation of, nutritional support in this audit were unclear. Although many patients had a noted contraindication to either EN or PN in isolation, no dog and only 1 cat had contraindications to both modalities. It is unclear why animals were not given nutrition when they had contraindications to only 1 nutritional modality. For many of the patients who received NNS, there was no noted contraindication to nutritional support, and no comment within the medical record as to why it was being withheld. Although appropriate vascular access for PN was present in 56.9% of animals, PN was not provided to the majority of these patients. Protocols used at the authors' institution likely account for the absence in some patients as PN may only be infused via a previously unused catheter port in an effort to reduce septic complications. Given the number of medications and infusions needed in critically ill patients undergoing MV, there may have been no unused ports for PN. From review of medical records, it was not possible to determine why only 2 dogs were fed via an enteral tube when 7 dogs had these in place. Of the remaining 5 dogs, only 1 had a documented contraindication noted in the medical record (ie, marked refractory ileus) to feeding via the device. It is common for animals weaned from MV to require ongoing oxygen supplementation and occupying a nostril with an enteral device may increase airway resistance or limit the maximum achievable FiO_2 with nasal supplementation. Although an esophagostomy tube with an intraluminally placed gastric, duodenal, or jejunal tube would avoid this problem, this specific procedure is cost prohibitive at the authors' institution. The cost of placing such a device could reduce finances available for the patient to remain on MV. These factors may account for the very low level of enteral feeding devices seen in this audit.

Due to differences between human and veterinary ICU populations, caution is warranted in the direct translation of human therapeutic guidelines to animals. What seems rational to conclude from the current human and veterinary data is that early provision of nutritional support is beneficial, even when caloric requirements are not fully met. Indeed, in mechanically ventilated people randomized to receive either hypocaloric "trophic" feeding or full caloric provision enterally for the first 6 days of MV, there was no difference in mortality or ventilator-free days, but a reduced incidence of gastrointestinal intolerance to feeding in the trophic group.[25]

The most obvious limitation of this audit is that it outlines nutritional support at a single institution, which therefore limits its applicability to other centers. Despite this limitation, it is the first such audit of nutrition in cats and dogs receiving MV and is intended to highlight barriers to nutritional support in this population. Other limitations include the inherent retrospective nature of audits and include reliance on appropriate data recording in the patients' medical records. Although records that lacked the objective data were excluded from the audit, the assessment of contributory factors for delayed or absent nutrition was hampered by the lack of notes in the medical record. It also became apparent that specific contraindications to nutrition could have been present but not noted in the medical record. In cases where the exact length of time with no caloric intake prior to hospitalization could not be precisely determined, we opted to use the nearest 12-hour period of known absent caloric intake. This will have resulted in some patients having absent intake for longer than calculated and thus appear to be at reduced need for nutritional provision. Similarly, the prehospitalization period of absent caloric intake was unknown for 6 dogs and 4 cats, which likely led to underestimation of nutritional requirements in these cases. The difficulty in being able to quantify nutritional status prior to hospital admission, along with the very low number of patients with a recorded BCS, made rigorous assessment of the need for nutritional provision prior to ventilation difficult. Although no mechanical or septic complications were noted in patients receiving PN in this audit, it is possible that some animals suffered such complications but that these were not noted within the medical record. As previously mentioned, specific institutional protocols and costs (such as the need to reserve a vascular port for PN at catheter placement and high cost to place gastrostomy and duodenostomy tubes) will further limit the usefulness of this audit to institutions other than our own. Despite its limitations, this audit highlights a lack of adequate nutritional provision for many patients at this institution, with many having no obvious reason for this oversight.

The majority of animals described in this clinical audit received NNS (68% of dogs, 75% of cats), and in many cases a well-defined reason could not be determined from the medical record. Although many animals in this audit had contraindications to one feeding modality, it remains unclear why another modality was not used. In light of various proposed clinical standards, clinicians should be cognizant of the potential benefits of nutrition in the critically ill, mechanically ventilated dog and cat. Clinical audits, especially when repeated after changes in policy or protocols, may be a valuable tool to drive institutional improvements. This audit should be repeated after changes in institutional protocols are performed to assess for any effect on morbidity or mortality. Further work is needed to better define the nutritional requirements of critically ill veterinary patients, evaluate the most appropriate modality, and determine feeding protocols that optimize outcome while minimizing risks.

CONFLICT OF INTEREST

Dr Chan is the Editor of the Journal, but did not participate in the peer review process other than as an author. The authors declare no other conflict of interest.

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APPENDIX A

MAJOR DIAGNOSES AND CONCURRENT COMORBIDITIES IN 50 DOGS UNDERGOING MECHANICAL VENTILATION

Dog	Diagnosis	Comorbidities
1	Aspiration pneumonia	Megaesophagus
2	Aspiration pneumonia	BOAS, atrial fibrillation, pulmonic stenosis, AKI, UTI, HGE
3	Aspiration pneumonia	Pericardial mesothelioma and pericardial effusion, regurgitation
4	Coma (unknown cause)	None noted
5*	Recurrent aspiration pneumonia	BOAS, pneumothorax
6	Rhabdomyolysis	Glossitis
7	Neurogenic pulmonary oedema	Idiopathic epilepsy
8*	Aspiration pneumonia	BOAS
9*	Non-cardiogenic pulmonary oedema	Ileus
10	Bacterial pneumonia	Angiostrongylus vasorum with aberrant migration (lung, kidney, and liver), VAP
11	Pulmonary arterial and venous neoplastic embolic disease	Renal cell carcinoma
12	Multiple organ dysfunction syndrome and ARDS	Gastric dilatation volvulus, anuric AKI, arrhythmias
13	Neuromuscular disease (type not known)	None noted
14	Bacterial pneumonia	BOAS
15	Aspiration pneumonia	Sepsis with refractory hypotension, vomiting
16	Bacterial pneumonia	Neuromuscular disease
17	ARDS (cause unknown)	None noted
18	Multiple organ dysfunction syndrome and ARDS	Cricopharyngeal achalasia, regurgitation, aspiration pneumonia
19*	Aspiration pneumonia	BOAS, tracheostomy
20	Negative pressure pulmonary oedema	Third degree AV block
21	Bacterial pneumonia	AKI
22*	Aspiration pneumonia	Gastric dilatation volvulus, azotemia
23*	ARDS (inhaled irritant)	Hypothyroidism
24	Toxin (suspected metaldehyde)	Anemia
25	Aspiration pneumonia	BOAS, intervertebral disc disease
26*	Metastatic neoplasia	None noted
27*	Aspiration pneumonia	BOAS, upper respiratory tract obstruction
28	Pulmonary hypertension	Chronic pulmonary parenchymal disease, patent foramen ovale, atrioventricular valve disease
29	Head trauma with foramen magnum herniation	SIADH
30	Aspiration pneumonia	Gastrointestinal foreign body
31	Multiple organ dysfunction syndrome with ARDS	Hypophysectomy, anuric AKI, pneumothorax
32*	Aspiration pneumonia	None noted
33	Thoracic trauma	Pulmonary contusions
34*	Aspiration pneumonia	BOAS
35	Thoracic trauma	Pulmonary contusions, pneumothorax, spinal fractures
36	Bacterial pneumonia	Pyothorax, vasopressor refractory hypotension
37	Polytrauma	Pulmonary contusions, rib fractures, diaphragmatic hernia, coxofemoral luxation
38*	Cervical myelopathy	None noted

(Continues)

Dog	Diagnosis	Comorbidities
39	Aspiration pneumonia	Sepsis, pleural effusion, pneumothorax, history of vomiting
40	Upper airway obstruction following mitral valve repair	Hyperadrenocorticism
41	Sterile lipid pneumonia	None noted
42*	Aspiration pneumonia	BOAS, hydrocephalus, history of vomiting and regurgitation
43*	Aspiration pneumonia	BOAS, laryngeal obstruction
44*	Thoracic trauma	Cervical myelopathy, scapular fractures, pneumothorax
45	Unknown	Enteritis
46	Polytrauma	Pulmonary contusions, pneumothorax, skull fractures, anemia, hemoabdomen
47	Multiple organ dysfunction syndrome with ARDS	Myocardial dysfunction, AKI, neutropenia, vomiting
48*	Aspiration pneumonia	AKI, myocardial dysfunction, vomiting, intervertebral disc disease, adrenal mass lesion, precursor directed IMHA
49*	Polytrauma	Pulmonary contusions, hemoabdomen
50	Multiple organ dysfunction syndrome with ARDS	Pyothorax, thrombocytopenia, myocardial dysfunction, anuric AKI

Abbreviations: AKI, acute kidney injury; ARDS, acute respiratory distress syndrome; AV, atrioventricular; BOAS, brachycephalic obstructive airway syndrome; HGE, hemorrhagic gastroenteritis; IMHA, immune mediated hemolytic anemia; SIADH, syndrome of inappropriate antidiuretic hormone secretion; UTI, urinary tract infection; VAP, ventilator associated pneumonia.

*Survived to discharge.

APPENDIX B

MAJOR DIAGNOSES AND CONCURRENT COMORBIDITIES IN 8 CATS RECEIVING MECHANICAL VENTILATION

Cat	Diagnosis	Comorbidities
1	Lymphoma	None noted
2*	Asthma	Nasopharyngeal stenosis, multiple rib fractures, pneumothorax, hypokalemia, historical vomiting and regurgitation, azotemia
3	Polycythemia vera	Hypertrophic cardiomyopathy
4	Ureteral obstruction	Bilateral nephropathy
5	Neuromuscular disease (junctionopathy)	None noted
6	Pituitary mass lesion	Syringomyelia and tetraparesis
7*	Fibronecrotizing pleuritis and pneumonia	Pancreatic cysts
8	Ureteral obstruction	Bilateral nephropathy

*Survived to discharge.