Aspiration pneumonia: assessing the risk of regurgitation in the cat

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Depending on the population characteristics, 12 to 80 per cent of patients undergoing elective surgery exceed the current risk criteria for aspiration pneumonitis (gastric volume ≥ 0.4 ml·kg^{-1} and pH ≤ 2.5), in sharp contrast to the actual incidence of the disorder, estimated at 0.01 per cent. Improved specificity would likely result if the risk of regurgitation was also considered, in addition to the volume and pH criteria. As a first attempt to assess the risk of regurgitation under general anaesthesia, we measured the minimal gastric volume (VR) required to produce regurgitation in cats anaesthetized with ketamine. The mean was 20.8 ml·kg^{-1} (n = 7, range: 8–41, SD = 7.8). We conclude that the residual gastric volume needed to produce a regurgitation under general anaesthesia is at least 20 times greater than the volume required to produce pulmonary damage by intratracheal injection (0.3 ml·kg^{-1}, assuming a pH of 2.5 or less).

Key words

COMPLICATIONS: aspiration pneumonitis, regurgitation; ANAESTHESIA: general.

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Identifying patients at risk of developing aspiration pneumonia during the course of general anaesthesia is of primary importance. Although patients with known predisposing factors (e.g., pregnancy, obesity) are easily recognized, assessing the risk of aspiration pneumonia for normal patients is difficult. The current approach is to evaluate the capability of the gastric contents to produce pulmonary damage, assuming that the entire residual gastric volume reaches the tracheo-bronchial tree.[1] The threshold for pulmonary damage is derived from animal studies showing that severe pulmonary lesions follow direct intra-tracheal injection of at least 0.4 ml·kg^{-1} of gastric fluid with a pH of 2.5 or less.[2] The proportion of elective surgical patients exceeding these criteria, and thus considered at risk, ranges from 12 to 80 per cent depending on the patient population characteristics.[3,4]

The main disadvantage of this approach is its low predictive value, the incidence of aspiration pneumonia being estimated at one per 10,000 cases.[5] Improved specificity would likely be achieved if the risk of regurgitation per se could be considered along with the damaging potential of gastric content. Active vomiting can also be the initial event leading to aspiration pneumonia. Only (passive) regurgitation will be considered in this study, since active vomiting appears to be less frequent with currently used rapid IV induction sequences (as opposed to mask inductions with the older volatile agents).

Although the residual gastric volume is presumably in the normal individual the main variable which affects the risk of regurgitation, the relationship between these two factors has not been examined. In a first attempt to quantify this relationship we measured in the cat the minimal gastric volume

TABLE Results (mean ± S.D.)

	Anaesthetized no manometry	*Anaesthetized manometry*	*Awake manometry*	*Re-anaesthetized manometry*
Volume for regurgitation ($ml \cdot kg^{-1}$) (n = 7)	21.7 ± 9.3	18.8 ± 8.7	23.5 ± 12.9	19.1 ± 6.7
Range	(12–38)	(9–34)	(8–41)	(12–33)
Lower oesophageal sphincter resting tone (mmHg) (n = 4)	—	12.5 ± 8	14.4 ± 7	16.25 ± 4.1

*No significant difference was observed between groups, based on the Kruskal-Wallis test.[7]

((VR) or volume for regurgitation) required to produce regurgitation under general anaesthesia. The cat was chosen because it provides a good model of the human lower oesophageal sphincter (LOS).[6]

Methods

The overall plan was to slowly distend the stomach by a progressive injection of water tinted with methylene blue via a gastrostomy tube until regurgitation occurred. Manometric recordings were made to ascertain that the LOS was functioning normally.

Seven adult cats with a mean weight of 4.5 kg ± 0.85 were anaesthetized with ketamine ($10 mg \cdot kg^{-1}$) and acepromazine maleate ($1 mg \cdot kg^{-1}$) IM. The latter drug is routinely administered to limit the rigidity associated with the use of ketamine in cats. A 20-gauge catheter was inserted in an internal saphenous vein. The electrocardiogram and rectal temperature were monitored continuously and the animals were allowed to breathe spontaneously without tracheal intubation. Anaesthesia was maintained with the same agents, one fourth of the initial dose administered IV every 60–120 min. p.r.n.

A median laparotomy was performed to place the gastrostomy tube and to occlude the third portion of the duodenum. This last step was deemed necessary because pilot studies revealed that some of the injected fluid might escape through this route.

After closure of the abdominal wall, a continuously vented suction (14F Salem® Sump Tube, Argyle, St. Louis, Missouri) was inserted in the nasopharynx to ensure rapid detection of the regurgitated fluid.

The VR was always measured in triplicate. Adequate emptying of the stomach was verified before each determination by comparing the volume of the fluid injected in the stomach to the volume regurgitated plus the volume retrieved from the gastrostomy tube. When adequate emptying could not be ascertained, the abdominal wall was reopened to allow visual inspection of the stomach.

After a first baseline measurement of the VR, a second determination was obtained after inserting a standard triple lumen continuously perfused manometry catheter connected to three Bentley 800 transducers linked to a RM Beckman physiograph. The catheter was left in place until the end of the experiment. A third measurement was made after partial awakening of the animal, arbitrarily defined as the return of a motor response during laryngoscopy. After re-anaesthetizing the animal, a fourth measure was made to establish the reproducibility of the method by comparing the last results with those of the second measurement (Table).

Results

There were no significant differences in VR or LOS pressure between any two of the four conditions (Table). The mean VR for all observations combined was $20.8 ml \cdot kg^{-1}$ (SD = 7.8, n = 7).

Reliable manometry measurements of the LOS resting tone were obtained only in four animals. The mean resting LOS pressure was 14.4 mmHg (Table). Repeated equipment failure prevented recording with the three other animals. Recording attempts during the progressive gastric filling were not successful (see Discussion).

Discussion

Three conditions are necessary to produce aspiration pneumonia: (1) gastric contents must have the capability to inflict pulmonary damage; (2) regurgitation must occur; (3) a sufficient amount of the regurgitated material must reach the tracheobronchial tree.

Reliable criteria[8,9] are available for assessing the potential toxicity of the gastric content and we consider that further discussion on this topic is not required here. There is ample evidence that general anaesthesia blunts or suppresses the pharyngeal and laryngeal reflexes that would normally prevent condition #3 from occurring. It thus seems that when the trachea is neither protected by the normal reflexes or by an endotracheal tube (induction and emergence), the prevention of aspiration pneumonia depends solely on avoidance of regurgitation.

The risk of regurgitation depends on the balance between the intragastric pressure and the pressure of the LOS (barrier pressure). Known pathological conditions, which either increase the intra-gastric pressure or impair the function of the LOS,[10] increase the risk of regurgitation, irrespective of the residual gastric volume. In the normal individual, however, it is the residual gastric volume which establishes the intra-gastric pressure, and hence the risk of regurgitation.

This study was a preliminary attempt to quantify the relationship between the risk of regurgitation and the residual gastric volume in the normal cat under general anaesthesia with ketamine. The results show that a mean volume of 20.8 $ml \cdot kg^{-1}$ is required to produce regurgitation following progressive injection of fluid into the stomach. In view of the wide range of the data (8–41 $ml \cdot kg^{-1}$), prudence dictates that the lower limit be used as the criterion for risk of regurgitation. Despite this limitation, there seems to be definite evidence that the risk criterion for regurgitation (8 $ml \cdot kg^{-1}$) is much greater than that for pulmonary damage (0.4 $ml \cdot kg^{-1}$), assuming a direct intratracheal injection of fluid with a pH of 2.5 or less. This may account for the low predictive value of the current approach of estimating the risk of aspiration pneumonia. We suggest that viewing the risk of regurgitation as the product of the three following sequential risk factors would yield improved predictive value: (1) the risk of regurgitation; (2) the risk of aspiration of the regurgitated fluid; and (3) the risk of pulmonary damage from the aspiration.

The foregoing does not imply that the risk of regurgitation and aspiration pneumonia is negligible when the residual gastric volume is less than 8 $ml \cdot kg^{-1}$ or when the volume of gastric fluid *aspirated* is less than 0.4 $ml \cdot kg^{-1}$ since a multiplicity of factors can play a critical role in the pathogenesis of aspiration pneumonia. With the objective of the present experiment being examination of the relationship between the residual gastric volume and the risk of regurgitation, we inevitably had to ignore many other potentially important factors, such as abnormal LOS function, increased intragastric pressure, active vomiting, the presence of food particles or bacteria in the aspirated fluid, pre-existing pulmonary pathology. Thus, not fulfilling the above *risk* criteria is not synonymous with protection from regurgitation and aspiration pneumonia.

Manometric recordings were attempted to measure the resting tone of the LOS and the response to increments in gastric pressure. Adequate resting tone recordings obtained in four animals show a 60 per cent decrement when compared to values previously reported by this laboratory in awake animals under light sedation (acepromazine maleate 5 $mg \cdot kg^{-1}$ IM).[11] Although ketamine is not specifically mentioned, Cotton and Smith[10] reported that most general anaesthetics (volatile or IV agents) decrease LOS tone. Thus, the present experiment appears to replicate the usual LOS pressure decrease associated with general anaesthesia. The possibility that the recent surgical manipulations might have altered the LOS activity cannot be confirmed or ruled out as we found no relevant information in the literature.

It would have been interesting to correlate VR with LOS pressure changes during progressive gastric filling. Recordings were unsatisfactory because we were unable, despite repeated attempts, to maintain the catheter ports in adequate position relative to the oesophagogastric junction. However, we have no reason to suspect any pre-existing abnormality of the LOS in the animals, and the validity of the VR measurements are not affected by these particular technical difficulties.

The main conclusion of this study is that, despite a 60 per cent decrease in the resting tone of the LOS,

the residual gastric volume required to produce regurgitation in the normal cat under ketamine anaesthesia is much higher than the volume required to produce pulmonary damage by direct intratracheal injection (assuming a pH of 2.5 or less). While extrapolation requires caution, it is reasonable to suggest that the same may apply to humans and that this could explain the low predictive value of current risk criteria for aspiration pneumonitis. Follow-up human studies appear warranted.

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Résumé

D'après les critères usuels d'évaluation du risque de pneumonie d'aspiration (résidu gastrique ≥ 0.4 ml·kg^{-1}, pH ≤ 2.5), de 12 à 80 pour cent des patients se présentant pour chirurgie élective seraient à risque de cette complication. Ceci concorde peu avec la rareté de cet événement, dont l'incidence est évaluée à 0.01 pour cent. Une façon d'accroître la spécificité serait peut-être de considérer aussi le risque de régurgitation. Dans une première étape pour évaluer le risque de régurgitation sous anesthésie générale, nous avons mesuré le volume gastrique minimal requis pour provoquer une régurgitation chez le chat anesthésié avec de la kétamine. La valeur moyenne obtenue a été de 20.8 ml·kg^{-1} (n = 7, écart: 8–41, DS = 7.8). Il semble donc que le volume gastrique minimal requis pour provoquer une régurgitation sous anesthésie générale soit au moins 20 fois plus grand que le volume requis pour causer une pneumonie d'aspiration par injection intra-trachéale directe (0.4 ml·kg^{-1}, pH ≤ 2.5).