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Outcomes of dogs undergoing surgery for gastric dilatation volvulus after rapid versus prolonged medical stabilization

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Abstract

Objective: To compare the outcomes of dogs surgically treated for gastric dilatation volvulus (GDV) after rapid versus prolonged medical stabilization.

Study Design: Prospective cohort study, monoinstitutional.

Sample Population: One hundred and sixty-two dogs with GDV.

Methods: Dogs presenting with a GDV were allocated to 1 of 2 groups, *immediate* or *delayed*. In the *immediate* group, dogs were stabilized for 90 min prior to undergoing surgery. In the *delayed* group, dogs underwent surgery after at least 5 h of stabilization. Medical stabilization included gastric decompression and placement of an indwelling nasogastric tube to prevent further gastric dilatation in all dogs. Short-term outcomes were compared between surgical timings by univariate and multivariate analyses.

Results: Dogs ($n = 89$) in the *immediate* group underwent surgery a median time of 2.1 h after presentation (range 1.9-2.5 h), whereas those in the *delayed* surgery group ($n = 73$) were operated a median time of 9.8 h (range 5.4-13.7 h) after presentation. Survival rates did not differ between dogs undergoing immediate or delayed surgery at discharge (70/89 and 60/73, respectively) or at 1 month postoperatively (68/89 and 55/73, respectively). The degree of gastric torsion was differently distributed between the 2 groups ($P = .05$). In the *immediate* group, 19, 52, and 9 dogs had a 0°, 180° and 270° gastric torsion respectively, whereas in the *delayed* group, 27, 32, and 5 dogs had a 0°, 180° and 270° gastric torsion respectively. Hyperlactatemia 24 h after initiation of fluid therapy was associated with an increased in-hospital mortality risk and at 1 month postoperatively.

Conclusion: No survival benefit was detected as a result of proceeding to surgery after either a rapid or a prolonged medical stabilization.

Clinical Significance: The aggressive stabilization and monitoring protocol described here can be considered as an alternative to stabilize dogs with GDV

prior to surgery within 13.7 h of presentation. Further research is required to investigate the potential risks and benefits of prolonged over rapid stabilization and to identify candidates for each approach.

1 | INTRODUCTION

Gastric dilatation volvulus (GDV) is an acute, life-threatening condition that primarily affects large-breed dogs. Despite intensive treatment, including presurgical stabilization, surgery, and postsurgical care, mortality rates for dogs with GDV range from 10% to 27%, as reported in the last 2 decades.[1–6] Although the pathophysiology of GDV is complex and not fully understood, changes secondary to GDV are accepted as life-threatening. Rotation of the stomach causes dilatation, or dilatation may lead to rotation.[7] Gastric distension increases intra-abdominal pressure, reducing venous blood flow and increasing pressure on the diaphragm.[8] These changes may lead to inadequate coronary vessel flow and secondary myocardial ischemia, resulting in cardiac arrhythmias.[9,10] Meanwhile, increased intragastric pressure collapses gastric wall capillaries, eventually causing necrosis of the gastric mucosa and translocation of bacteria into the peritoneal cavity. Such changes predispose the dog to reperfusion injury during surgical derotation of the stomach.[11] Although the prognostic impact of the timing of surgery relative to presentation has been under debate, several authors have recommended surgery as soon as the animal's condition is stable.[6,12–14] Song et al. reported that an increased time from presentation to completion of surgical correction of GDV was associated with higher mortality, probably due to an increased duration of ischemia and a greater degree of organ injury.[6] In this study, the odds of mortality were more than doubled when surgery was not completed within 3 h of presentation.[6] Interestingly, Mackenzie et al. reported an inverse relationship between time from presentation to start of surgery and the overall mortality rate.[1] It is possible that the differences in the stabilization protocols employed and the case-by-case decision making regarding when to proceed to surgery in these retrospective studies may explain these conflicting conclusions. A "staged" approach to GDV was recently described, including gastric decompression and prolonged (a mean of 22.3 h) stabilization prior to a second anesthesia for corrective surgery. This protocol was associated with a mortality rate of 9% (3/35 dogs), which is similar to that of dogs undergoing immediate surgical correction of GDV.[15]

In our hospital, dogs that present with GDV at night are routinely stabilized overnight with decompression by trocarization, placement of a nasogastric tube and administration of intravenous fluids. Surgery is performed the next morning, once a complete team, including a specialist surgeon, is assembled. No prospective studies have compared the outcomes of dogs with GDV treated surgically after rapid or prolonged stabilization. The goal of our study was to compare the outcomes between these 2 groups. We hypothesized that dogs surgically treated after a prolonged period of stabilization would have a similar mortality rate to dogs surgically treated after a rapid stabilization.

2 | MATERIALS AND METHODS

Dogs diagnosed with GDV were included in the *immediate* group if they underwent surgery after 90 min of stabilization. Those undergoing surgery after a minimum of 5 h of stabilization were included in the *delayed* group. A minimum sample size of 57 dogs per group was calculated to detect a difference of at least 25% in mortality between immediate and delayed groups, with $\alpha = .05$, $1\text{-}\beta = .8$, and an estimated mortality rate of 15% in the immediate group.

2.1 | Inclusion criteria

Dogs presenting with GDV at our institution between January 2016 and October 2020 were prospectively enrolled in the study with informed consent from their owners. Owners were informed of the GDV treatment protocols at our institution; they were also informed of the current evidence surrounding risks and benefits of rapid versus prolonged stabilization. This study was approved by the clinical research committee at VetAgro Sup, Marcy l'Etoile, France (ethics committee number 1904-V2). A presumptive diagnosis of GDV was based on history and physical examination findings including abdominal distention, tympanic abdomen, resentment to abdominal palpation, panting, drooling and/or retching, and was subsequently confirmed by right lateral and dorsoventral abdominal radiographs.

Dogs were excluded if nasogastric tube placement was unsuccessful, if the dog never underwent surgery due to the owners electing for euthanasia or conservative management, if the dog was presented deceased, or if death occurred within 30 min of commencing stabilization.

2.2 | Preoperative management

2.2.1 | Initial resuscitation

A brief history was taken including time of onset of clinical signs and time of last meal. Complete physical examination included respiratory rate (RR), temperature, and perfusion parameters – heart rate (HR), pulse quality, capillary refill time (CRT), mucous membrane color, extremity temperature and mentation status. Bilateral cephalic intravenous (IV) cannulas (18 or 20 gauge) were placed once the presumptive diagnosis was confirmed on abdominal radiographic examination. A blood sample was taken at the time of cannula placement for hematological examination, a biochemistry panel (including plasma lactate concentration), prothrombin time (PT), and activated partial thromboplastin time (aPTT). A bolus of isotonic crystalloids (Ringer Lactate, 20 ml/kg IV), broad spectrum antibiotics (amoxicillin 20 mg/kg IV) and morphine (0.2 mg/kg IV) were administered. Time between presentation and initiation of IV fluids was recorded. Perfusion parameters (HR, pulse quality, CRT, mucous membrane color, extremity temperature and mentation status) and oscillometric systolic blood pressure (SBP) were reassessed 5 min after administration of the fluid bolus. Indications for a second bolus of 20 ml/kg of fluid were based on HR, CRT, and SBP. A second bolus (20 ml/kg) was administered if the SBP remained <90 mmHg and/or the CRT >2 s and/or the heart rate had not decreased by ≥15%. Parameters were reassessed 5 min later. If the systolic blood pressure of the dog remained <90 mmHg after 4 boluses (total shock dose), a dobutamine continuous rate infusion (CRI) was started at 5 μg/kg/min. The SBP was rechecked 5 to 10 min after initiation (or increased dosage) of the dobutamine CRI. The dose was increased by 2.5 μg/kg/min if the SBP remained <90 mmHg, and was further increased up to 20 μg/kg/min, if needed.

Oxygen therapy was initiated during initial fluid therapy; a nasal cannula was placed to administer a flow of 100 ml/kg/min of oxygen. A lidocaine CRI was also initiated (a bolus of 2 mg/kg IV followed by 50 μg/kg/min) to prevent cardiac arrythmias.[16] Continuous monitoring included a cageside 3-lead electrocardiogram (EKG) and oscillometric blood pressure monitoring (*Mindray* iPM10 monitor®). The stomach was decompressed with a 14 gauge cannula placed percutaneously at the area of greatest tympany after aseptic preparation of the overlying skin. This procedure was performed without additional sedation or local anesthetic. A nasogastric tube (Portex Horse Catheter, 20F, 137 cm) was placed in the free nostril without or under light sedation with propofol (0.5-2 mg/kg IV to effect), and left in place until surgery to prevent another gastric dilatation event. The nasogastric tube and the nasal cannula were secured to the skin with staples. Trocarization and placement of the nasogastric tube generally alleviated abdominal distention and/or tympany. When these results were not obtained, orogastric intubation was achieved under sedation with propofol (0.5-2 mg/kg IV to effect). HR, EKG and SBP were monitored continuously and data were recorded every 5 min over the initial 90 min period of stabilization for all dogs. Ninety minutes after initiation of IV fluid therapy, measurement of plasma lactate concentration was repeated.

2.2.2 | Case management

Dogs presented any day of the week between 8:00 a.m. and 7:00 p.m. were managed by 1 of 2 surgical specialists, overseeing collection of the history, patient examination, and administration of the described stabilization protocol, assisted by veterinary nurses. Dogs presented outside of these hours were managed by veterinary interns who had received prior instruction on GDV management, including patient enrolment and the stabilization protocol for this study. One of the 2 specialist surgeons was available via telephone at night to answer questions, or to assess the dog in person if it was considered necessary. A printed checklist was completed for each dog, to minimize deviations from the described stabilization protocol and omission of data (Appendix S1, in the supplementary material).

2.2.3 | Group assignment

All dogs that presented with GDV between the hours of 8:00 a.m. and 7:00 p.m. were allocated to the *immediate* group and taken to surgery after the initial 90 min stabilization period.

Dogs that presented with GDV outside of these hours were randomly allocated to either the *immediate* or the *delayed* group by a coin toss. If the dog was allocated to the *immediate* group, the interns initiated the stabilization protocol outlined above whilst contacting and awaiting the arrival of the specialist surgeon on call. The surgeon was then available to take the dog to surgery immediately after the initial 90 min stabilization period had ended. For dogs allocated to the *delayed* group via coin toss, the interns followed the same 90 min stabilization protocol outlined above, then continued crystalloids intravenously at a maintenance rate of 2 ml/kg/h, a continuous rate infusion of lidocaine (50 μg/kg/min), morphine (0.2 mg/kg IV, every 4 h), and oxygen therapy.

Dogs were maintained with continuous EKG and oscillometric blood pressure monitoring with data recorded every hour. A further blood sample was obtained for repeat hematology and biochemistry panel (including plasma lactate concentration), PT and aPPT, prior to induction.

2.2.4 | Surgical procedure

All surgeries were performed by 1 of 2 experienced surgeons; 1 European College of Veterinary Surgeons boarded surgeon (>10 years diplomate) and 1 nationally recognized surgical specialist (Diplôme d'études spécialisées vétérinaires with 20 years postgraduate experience).

Dogs were premedicated with midazolam (0.2 mg/kg IV) and morphine (0.2 mg/kg IV) and induced with propofol (4–6 mg/kg IV, to effect). Anesthesia was maintained with isoflurane and oxygen. Crystalloid IV fluids (Ringer Lactate) were administered at a rate of 10 ml/kg/h during the surgery. A midline celiotomy was performed and the degree of gastric rotation was recorded as 0°, 180°, 270°, or 360°. After gastric derotation, the extent of visible gastric wall damage was recorded as well as the degree of severity of the worse-damaged region via a color-based grading system of *scarce bruise*, *red*, *dark red* or *black* (Figures 1 and 2). A partial gastrectomy was performed when necrosis of the gastric wall was present. Briefly, the stomach was isolated with moistened laparotomy pads and stay sutures were placed. The affected tissue, along with an appropriate margin of grossly normal tissue, was sharply excised with a scalpel blade or Metzenbaum scissors. The defect was closed with a 2-layer pattern using 3–0 absorbable suture material. The mucosa and adherent layer of submucosa was closed with a simple continuous pattern, and the seromuscular layer was closed in a continuous Cushing pattern. Omentum was then tacked over the site. The stomach was permanently adhered to the body wall by incisional gastropexy as previously described.[13,17] Anesthesia time, surgical time, and any additional procedures performed under the same anesthetic episode were recorded.

2.2.5 | Postoperative care

Postoperative treatment included IV administration of lactated Ringer's solution (2–5 ml/kg/h depending on

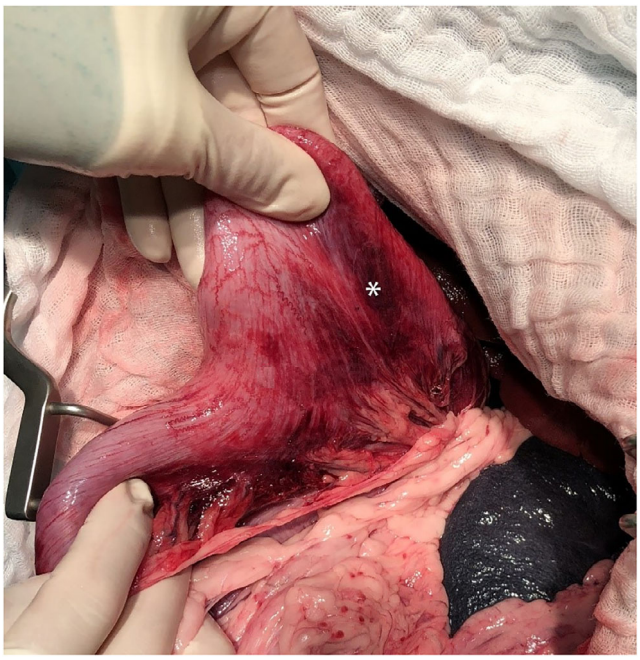

FIGURE 1 Intraoperative appearance of a damaged gastric wall after correction of the torsion. The extent of gastric wall damage was estimated to be 10%-25% with the worst injured area categorized as *dark red* (*)

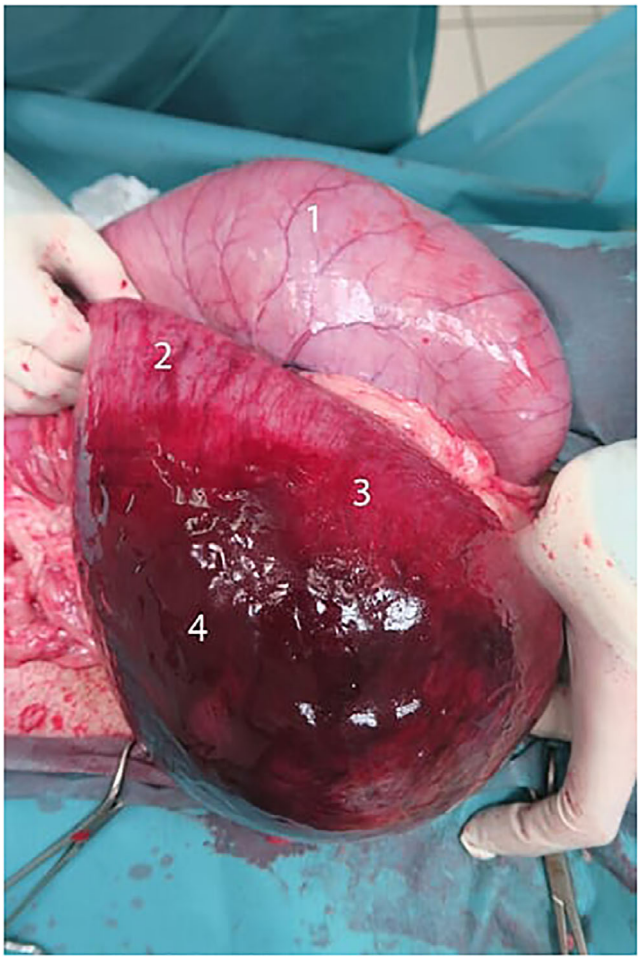

FIGURE 2 Color scheme used to grade the most severe damage of the gastric wall: normal serosa (1), *slight bruising* (2), *red* (3) and *dark red* (4)

hydration status), morphine (0.2 mg/kg IV, every 4 h), antimicrobials (amoxicillin 20 mg/kg IV, every 8 h), metoclopramide (0.3 mg/kg IV, every 8 h), and ranitidine (2 mg/kg IV, every 8 h). For as long as the dogs remained hospitalized, blood pressure and EKG were recorded every 15 min for the first 5 h, every hour for the next 20 h, every 2 h for the subsequent 24 h, and every 4 h thereafter. The exception to this was dogs with cardiac arrhythmias for whom recording was continued every 15 min. Every record also included RR, HR, CRT, and rectal temperature recorded at least 6 times a day, and duration of hospitalization.

Serum creatinine, urea and albumin levels, plasma lactate concentration and PT and aPTT were rechecked 12 and 24 h after the onset of IV fluid administration. Hypotension was defined as systolic blood pressure <90 mmHg or mean arterial pressure <60 mmHg at any time during hospitalization. Acute renal failure was diagnosed when dogs had a serum creatinine concentration >2 mg/dl after 24 h of fluid administration, and disseminated intravascular coagulation (DIC) was suspected when dogs had a sudden drop in circulating platelet count accompanied by a mild to moderate prolongation (20%–30%) of aPTT and clinical signs of DIC (petechiae, ecchymoses, hematochezia, melena, hematemesis, hematuria, signs of shock or signs of hypovolemia) as previously described.[18]

The lidocaine CRI was discontinued after 24 h unless premature ventricular complexes (PVC) were being observed. In such cases, the lidocaine CRI was then continued until PVC disappeared or the dog was discharged. Dogs were discharged when they were bright and alert, with normal physical examination findings. Tramadol (3–5 mg/kg orally 3 times a day) and metoclopramide (0.4 mg/kg orally twice daily) were administered for 5 and 10 days, respectively. Owners were also advised to give a high-fiber diet for 1 month and to divide the daily food ration into 2 or 3 meals per day for at least 1 month.

2.2.6 | Follow up

Survival to discharge was recorded. Some dogs were re-evaluated at our institution 5 days postoperatively and for suture removal 15 days postoperatively but most were re-evaluated by their local veterinarian. Survival after 1 month was established via telephone conversation with the owners.

2.3 | Statistical analysis

For descriptive statistics, continuous data were assessed for Gaussian distribution by histogram evaluation and the Shapiro-Wilk test (Gaussian if $P > .05$). Gaussian data were presented using means and standard deviations; non-Gaussian data were presented using medians and ranges. Categorical data were presented as number of dogs and percentages. Univariate association between *immediate/delayed* and survival at hospital discharge or 1 month after surgery was assessed by a χ^2 test. Potential confounders were considered as variables associated with the *immediate* and *delayed* groups and survival that might change the statistical relationship between these 2 variables. Statistical associations between 44 candidate variables and being operated on after a 90 min stabilization or after at least 5 h of stabilization were analyzed by Student *t*-test or 1-way ANOVA (if Gaussian) or Mann-Whitney test (if not Gaussian) for continuous variables, and by χ^2 test (if expected frequencies >5) or Fisher exact test (if expected frequencies <5) for dichotomous or categorical variables.

Statistical associations between all candidate variables with $P < .1$ and survival at discharge and 1 month after surgery were studied using the same statistical tests listed above. Variables with $P < .1$ at both analyses were retained as potential confounders and were selected for multivariable logistic regression, with survival at hospital discharge or 1 month after surgery as the dependent variable and being operated on after a 90 min stabilization or after at least 5 h of stabilization and the potential confounders as independent variables. Specification errors and goodness-of-fit of the logistic regression were assessed using the linktest and lfit functions of the statistical software. All statistical analyses were performed with a commercially available software package (STATA, version 14.0, StataCorp LP, College Station, Texas), with significance level set at $P < .05$ unless otherwise specified.

3 | RESULTS

3.1 | Demographics

Over the study period, 244 dogs were presented with GDV. Three dogs were excluded because nasogastric tube placement was unsuccessful. Seventy nine dogs (32%) were not taken to surgery and were therefore excluded. Reasons for this exclusion included euthanasia (64 dogs), owners electing conservative treatment (8 dogs), presented deceased (4 dogs), and death occurring within 30 min of commencing stabilization (3 dogs). A total of 162 dogs were included in the study, 89 in the *immediate* group and 73 in the *delayed* group.

Among the 162 dogs included in the study, 29 breeds were represented, with German shepherds (33 dogs, 20%), Great Danes (16 dogs, 10%), and Bernese mountain

dogs (11 dogs, 7%) being the most commonly represented pure breeds. No statistical difference was noted between *immediate* and *delayed* groups regarding breed ($P = .87$), sex distribution ($P = .33$), or age at surgery ($P = .90$).

3.2 | Preoperative findings

Median time between onset of clinical signs as reported by the owners and presentation was 180 min (range: 15–1200 min) and 130 min (40–1200 min) for dogs in the *immediate* and *delayed* groups, respectively ($P = .16$). No difference was identified in time between the last meal and presentation between the 2 groups ($P = .68$). Median time between presentation and fluid therapy initiation for the *immediate* group was 10 min (range: 2–55 min). For the *delayed* group it was 15 min (range: 2–75 min). It did not differ between groups ($P = .16$). Clinical signs at presentation (tachypnea, tachycardia, hypotension or rectal temperature) did not differ between groups.

The only difference identified on blood tests at admission consisted of the Alkaline Phosphatase (ALP) activity, which was higher in the *immediate* group (median 86 U/I, range 22–891 U/I) compared with the *delayed* group (median 53 U/I, range 10–738 U/I, $P = .001$). Among the 162 dogs, 14/162 presented with stress leucogram, 45/162 with thrombocytopenia, 35/162 with anemia, and 8/162 with prolonged coagulation parameters (PT and aPTT).

Plasma lactate concentration at time of admission was not different between groups (median 4.71 mmol/L, range 1.20–12 mmol/L versus 4.63 mmol/L, range 1.38–12 mmol/L for *immediate* and *delayed* groups, respectively, $P = .41$). There was no difference between groups for plasma lactate concentration after the first 90 min of stabilization (median 2.52 mmol/L (range 0.65–12 mmol/L) versus 2.47 mmol/L (range 0.78–8.97 mmol/L) for *immediate* and *delayed* groups, respectively, $P = .51$). There was also no difference between groups for plasma lactate concentration 12 h following initiation of fluid therapy (median 1.58 mmol/L, range 0.50–5.17 mmol/L versus 1.66 mmol/L, range 0.68–7.14 mmol/L for *immediate* and *delayed* groups, respectively, $P = .78$). However, lactate at 24 h after initiation of fluid therapy (therefore after surgery in all cases) was lower in the *immediate* group (median 1.38 mmol/L, range 0.60–6.04 mmol/L) in comparison with the *delayed* group (median 1.70 mmol/L, range 0.69–6.01 mmol/L, $P = .008$).

3.3 | Surgical procedure

Surgery was performed after 90 min of medical stabilization for all dogs in the *immediate* group. The dogs in this group underwent surgery a median time of 2.1 h after presentation (range 1.9–2.5 h). For the dogs in the *delayed* group the median time between presentation and surgery was 9.8 h (range 5.4–13.7 h). Duration of anesthesia (median 79 min, range 40–150 min versus 80 min, range 45–240 min for *immediate* and *delayed* groups, respectively) and the duration of surgery (median 30 min, range 15 to 75 versus 30 min, range 15 to 105, for *immediate* and *delayed* groups, respectively) did not differ between groups ($P = .28$ and $P = .43$, respectively).

Five dogs [6%] in the *immediate* group had a partial gastrectomy and 3 of those did not survive to discharge. Four dogs [5%] in the *delayed* group had a partial gastrectomy and 3 of those did not survive to discharge.

Eight dogs (9%) in the *immediate* group required additional procedures. Three dogs required gastrotomies for foreign body retrieval (1 of which did not survive to discharge) and 1 dog underwent a splenectomy (and did not survive to discharge). Two dogs required suturing of tears in the capsule of the spleen to address hemorrhage, 1 of which did not survive. One dog had a liver biopsy and survived, and finally 1 dog had a cholecystectomy performed and did not survive. In the *delayed* group, 7 dogs [10%] underwent additional procedures; gastrotomies for foreign body retrieval in 5 dogs (all survived) and splenectomies in 2 dogs (none survived to discharge).

The degree of gastric torsion was differently distributed between the 2 groups ($P = .05$) with more 0° and fewer 180° and 270° torsions in the *delayed* group in comparison with the *immediate* group. In the *immediate* group, 19, 52, and 9 dogs had a 0°, 180° and 270° gastric torsion respectively, whereas in the *delayed* group, 27, 32, and 5 dogs had a 0°, 180°, and 270° gastric torsion respectively.

In addition to the 5 dogs in the *immediate* group that underwent partial gastrectomy to address gastric wall necrosis, 2 other dogs in the *immediate* group had gastric wall necrosis but were euthanized during surgery as >90% of the gastric wall was affected. Four dogs in the *delayed* group had gastric wall necrosis and, for all of them, a partial gastrectomy was performed. The proportion of gastric lesions and severity of gastric lesions did not differ between groups ($P = .16$ and $P = .21$, respectively). The presence of gastric necrosis (ie, *black* color) was almost equally frequent in both groups (8% in the *immediate* group and 5% in the *delayed* group).

3.4 | Outcomes

The duration of hospitalization time did not differ between the 2 groups, ranging from 1 to 5 days (median 2 days) in the *immediate* group and from 1 to 4 days

TABLE 1 Association between immediate or delayed surgery and death before hospital discharge and at 1 month postoperatively in 163 dogs undergoing surgical correction of gastric dilatation-volvulus. Only the 3 potential confounding variables are presented here

	Death prior to hospital discharge		Death within 1 month after surgery	
Variables	**Adjusted OR (95% CI)**	***P***	**Adjusted OR (95% CI)**	***P***
Delayed surgery compared with immediate	0.88 (0.13–6.29)	.91	2.29 (0.48–10.9)	.30
Hyperlactatemia 24 h after initiation of fluid therapy	2.44 (1.23–4.83)	**.01**	2.05 (1.12–3.75)	**.02**
Extent of gastric lesion compared to 0%	5%–10%: 1.18 (.04–31.81)	.92	5%–10%: 1.07 (.11–9.63)	.95
	10%–25%: 2.85 (.15–54.66)	.47	10%–25%: 1.70 (.21–13.24)	.61
	25%–50%: 10.06 (.69–146)	.09	25%–50%: 5.80 (.78–43.07)	.09
	>50%: 2.86 (0.01–36.48)	.58	>50%: 5.23 (.34–79.32)	.23
Persistent tachycardia	3.00 (0.37–24.31)	.30	7.27 (1.47–35.90)	**.015**

Abbreviations: CRT, capillary refill time; EKG, electrocardiogram; HR, heart rate; IV, intravenously; PVC, premature ventricular complex; RL, ringer's lactate solution; RR, respiratory rate; SBP, systolic blood pressure. Significant results ($P<0.05$) are bolded.

(median 2 days) in the *delayed* group ($P = .64$). No differences were found between the 2 groups regarding persistent tachycardia, tachypnoea, hypotension, hypothermia, coagulopathy, and AKI postoperatively. Fewer dogs in the *delayed* group (9/73) developed PVC compared to the *immediate* group (19/89) ($P = .07$).

The overall survival rate was 80% (130/162) at discharge and 76% (123/162) 1 month postoperatively. No difference in survival rate was found between the *immediate* (70/89, 79%) and *delayed* (60/73, 82%) groups at discharge ($P = .57$) or 1 month postoperatively (68/89 (76%) and 55/73 (75%) for *immediate* and *delayed* groups, respectively, $P = .80$). Among the 19 dogs in the *immediate* group who died prior to discharge, death occurred from cardiorespiratory arrest during general anesthesia for 12/19 dogs, either at induction, during surgery, or during the recovery period (<1 h after the end of surgery). Two dogs were euthanized during surgery due to extensive (>90%) gastric wall necrosis, and another was euthanized the day following surgery because of septic peritonitis after gastrectomy. The 4 remaining dogs died between 12 and 24 h after surgery from cardiorespiratory arrest.

Among the 13 dogs in the *delayed* group who died prior to discharge, 3 dogs died between the first 30 and 90 min of stabilization and 1 dog died during the period after the first 90 min of stabilization and before any general anesthesia, 5 h after presentation. Death occurred from cardiorespiratory arrest during general anesthesia for 2/13 dogs. Five dogs died less than 12 h after the surgery from cardiorespiratory arrest. Two dogs died between 12 and 24 h after surgery, with suspected DIC.

Three potential confounding factors were identified by univariate analyses and were therefore included in the multivariable models; plasma lactate concentration 24 h after commencing fluid therapy, extent of gastric lesions, and persistence of tachycardia during hospitalization. After controlling for them, there was no association between death prior to hospital discharge and at 1 month postoperatively and *immediate* and *delayed* groups ($P = .91$ and $P = .30$, respectively). Only hyperlactatemia 24 h after commencing fluid therapy was associated with death prior to hospital discharge and at 1 month postoperatively on multivariate analysis ($P = .01$ and $P = .02$ respectively) (see Table 1). Persistence of tachycardia during hospitalization was associated with death at 1 month postoperatively on multivariate analyses ($P = .015$).

4 | DISCUSSION

Gastric dilatation volvulus has historically been considered a surgical emergency[12–14] requiring intervention after a short period of stabilization. At our hospital, dogs presented with GDV at night are routinely stabilized overnight and operated the following morning to avoid a perceived "night effect" – namely a perceived worse outcome associated with being taken to the operating room overnight by a smaller and/or less experienced team. "Night effect" or "night and weekend syndrome" refers to the increased mortality reported in human patients admitted and/or operated on outside of normal working hours.[19–22] In a recent study conducted at 2 specialist veterinary referral and emergency centers, the odds of mortality were doubled when dogs with GDV were operated by general surgeons rather than specialist surgeons.[6] In that study, board-certified specialist surgeons were categorized into the specialist group whereas emergency

veterinarians, residency-trained board-eligible surgeons, residents, and interns were categorized into the general surgeon group. At our hospital, as perhaps at other referral centers, specialist surgeons are only available during the day, with general surgeons operating on any cases urgently requiring surgery at night, typically with a smaller team of support staff. Our hospital's practice of only operating on GDV cases during the day ensures that all cases are operated on by a specialist surgeon but it was previously unclear whether the delay in going to surgery which the night-presenting cases resultantly endure was detrimental to outcome. *Song* et al. suggested it could be, whereas the work of *Mackenzie* et al. suggested such a delay may actually be beneficial.[1,6] In a departure from typical practice for the purposes of this study, the specialist surgeons were made available to operate on any GDV cases presenting at night that had been randomly allocated to the *immediate* group. A fully randomized study design in which GDV cases presenting during the day were also randomly allocated by coin toss to either the *delayed* or *immediate* group would have been preferable but this would have led to some cases presenting during the day not being operated on until the night with a smaller team of support staff. The authors felt this was too great a departure from the currently accepted "gold standard" of GDV case management. Nonetheless, we recognize this as a potential source of introduction of bias, and a limitation to our study design.

As far as the authors are aware, the present report is the first prospective study to compare the outcome between dogs treated surgically for GDV after rapid (90 min) versus after prolonged (≥5 h) medical stabilization. The results support our hypothesis that dogs treated surgically after a prolonged medical stabilization would have a similar mortality rate to those surgically treated after a rapid stabilization; the survival rate to discharge did not differ between our 2 populations of dogs (70/89, or 79% for the *immediate* group and 60/73, or 82% for the *delayed* group). Our results contrast with those of Song et al.,[6] who reported increased mortality when surgery was completed more than 3 h after presentation. Our results also differ from those of Mackenzie et al.,[1] who reported that an increased time from presentation to start of surgery was associated with a lower overall mortality rate.

It is possible that the differing results for these 3 study populations may be associated with differing stabilization protocols – the lack of a clearly defined "endpoint" to stabilization of GDV cases is certainly an obstacle to investigating the effect of timing of surgery after presentation. Our results support the conclusions of White et al., according to whom a successful decompression and stabilization prior to surgical correction of GDV in dogs might allow delays in surgery.[15] In this study, the mean interval between presentation and surgery (22.3 h) was approximately double the longest surgical delay in our study (13.7 h), yet the survival rate reported by White et al. for their dogs (32/35, 91%) was more favorable than in our study.[15] Rather than supporting further delays in surgical intervention, these findings justify a thorough evaluation of stabilization protocols. The detection of hemorrhagic gastric lavage contents prompting concern for gastric necrosis was cited as a reason for withdrawing 3 dogs from the delayed surgery protocol in the study by White et al.; however this clinical sign did not seem associated with the health status of the gastric wall at laparotomy, or survival to discharge.[15] Gastric necrosis certainly appears to influence prognosis in dogs with GDV[1,5] but these lesions remain difficult to diagnose preoperatively.[2,23,24] As proposed by White et al., further research should focus on identifying the diagnostic/prognostic value of gastric lavage contents analysis, perhaps employing a validated visual scoring chart and/or serial assessment. Preoperative diagnosis of gastric necrosis may become a key determinant of the suitability of delayed management of dogs with GDV.

The findings of this study do not seem to justify changes in our current practices but equally they do not provide evidence of benefits in delaying surgery beyond the initial 90 min stabilization. We hope that the detailed inclusion of our preoperative stabilization protocol, targets, and monitoring practices will encourage similar transparency in future research regarding GDV surgery and contribute to evidence-based protocols. In the meantime, ill-defined endpoints and variability in preoperative stabilization continue to hinder interpretation of data surrounding surgical timing for dogs with GDV.

In our study, hyperlactatemia 24 h after initiating fluid therapy was associated with in-hospital death. This finding is consistent with the study by Zacher et al.,[3] in which dogs that survived until discharge from the hospital had lower initial and final plasma lactate concentrations and a larger percentage decrease in plasma lactate concentrations than dogs euthanized or deceased before discharge. Interestingly, lactate levels measured 24 h after starting fluid therapy were lower in dogs undergoing immediate surgery (median 1.38 mmol/L) than those whose surgery was delayed (median 1.70 mmol/L, $P = .008$). This statistical difference does not seem to translate into clinical relevance, specifically survival, perhaps because most individual values in both groups were within the normal range.

During delayed surgeries, GDVs were found to include more 0° degree and fewer 180° and 270° torsions than during immediate interventions ($P = .05$). This

finding could be explained by preoperative resolution of volvulus, reported after gastric decompression with placement of an orogastric tube alone, trocarization alone, or a combination of both.[15,25] However, spontaneous resolution of gastric torsion after gastric decompression and lavage can lead to recurrence of gastric volvulus.[15] This highlights the importance of continued close monitoring of patients allocated to a *delayed* protocol. Trocarization seems advantageous in comparison with orogastric tubing as this technique does not require sedation of hemodynamically unstable dogs.[25] However, a nasogastric or orogastric tube should be maintained preoperatively if surgery is delayed, to prevent recurrence of gastric distention.

Dogs in our study were more likely to die during anesthesia when surgery was scheduled immediately rather than delayed. Dogs operated after a short resuscitation may be less stable under anesthesia, emphasizing the importance of preoperative management. However, to date, no clear endpoints or ideal duration have been established for this resuscitation. Indeed, in most studies, surgery was performed when the patient was estimated stable enough to undergo anesthesia based on predetermined resuscitative parameters (eg, HR, RR, pulse quality, arterial blood pressure, capillary refill time, and color of the mucous membranes) without clear thresholds being identified.[6,12,16]

5 | CONCLUSION

In this study, aggressive stabilization and monitoring of dogs with GDV, including placement of an indwelling nasogastric tube, allowed surgery to be delayed by up to 13.7 h (median 9.8 h) with no apparent reduction in survival. However, no survival benefit was detected with a prolonged (>5 h) over a rapid (90 min) stabilization. Veterinary surgeons must keep in mind that achieving and maintaining gastric decompression are key to the stabilization of dogs with GDV and prerequisites when considering delays in surgical treatment.

The protocol reported in this study when surgery is delayed may be relevant when dogs must be transferred to another facility, or to allow surgery during the daytime when a full team is present. Two prognostic factors for survival were identified in this study; hyperlactatemia 24 h after initiation of fluid therapy was associated with an increased mortality risk in-hospital, and persistent tachycardia during hospitalization was associated with mortality in the first month postoperatively. Further research is required to identify preoperative variables that may guide the decision making process of surgeons.

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Author Contributions

Lhuillery E, DVM: wrote the article and helped with the acquisition of the data. Velay L, DVM: helped to write the article and assisted with the acquisition of the data. She critically revised the draft work. Libermann S, DVM, DESV Surgery: contributed to the design of the study, performed the surgery, and critically revised the draft work. Le Boedec K, DVM, MS, Dip. ACVIM(SAIM), Dip. ECVIM-CA: was responsible for statistical analysis. Gautherot A, DVM: helped to write the article and assisted with the acquisition of the data. Bonneau L, DVM: helped to write the article and assisted with the acquisition of the data. Mongellas E, DVM: helped to write the article and assisted with the acquisition of the data. Harris K, BVetMed, DipECVS, MRCVS: helped with the English translation of the article. She critically revised the draft work. Etchepareborde S, DVM, Dip. ECVS: designed the study, performed the surgery, and critically revised the draft work. All authors gave their final approval of the version to be published, ensuring that questions related to the accuracy of any part of the work were appropriately investigated and resolved.

CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this report.

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REFERENCES

1. Mackenzie G, Barnhart M, Kennedy S, DeHoff W, Schertel E. A retrospective study of factors influencing survival following surgery for gastric dilatation-volvulus syndrome in 306 dogs. *J Am Anim Hosp Assoc*. 2010;46(2):97-102.
2. Beer KA, Syring RS, Drobatz KJ. Evaluation of plasma lactate concentration and base excess at the time of hospital admission as predictors of gastric necrosis and outcome and correlation between those variables in dogs with gastric dilatation-volvulus: 78 cases (2004-2009). *J Am Vet Med Assoc*. 2013;242(1):54-58.
3. Zacher LA, Berg J, Shaw SP, Kudej RK. Association between outcome and changes in plasma lactate concentration during presurgical treatment in dogs with gastric dilatation-volvulus: 64 cases (2002-2008). *J Am Vet Med Assoc*. 2010;236(8):892-897.
4. Buber T, Saragusty J, Ranen E, Epstein A, Bdolah-Abram T, Bruchim Y. Evaluation of lidocaine treatment and risk factors for death associated with gastric dilatation and volvulus in dogs: 112 cases (1997-2005). *J Am Vet Med Assoc*. 2007;230(9):1334-1339.

5. Beck JJ, Staatz AJ, Pelsue DH, et al. Risk factors associated with short-term outcome and development of perioperative complications in dogs undergoing surgery because of gastric dilatation-volvulus: 166 cases (1992-2003). *J Am Vet Med Assoc*. 2006;229(12):1934-1939.
6. Song KK, Goldsmid SE, Lee J, Simpson DJ. Retrospective analysis of 736 cases of canine gastric dilatation volvulus. *Aust Vet J*. 2020;98(6):232-238.
7. Brockman DJ, Holt DE, Washabau RJ. Pathogenesis of acute canine gastric dilatation-volvulus syndrome: is there a unifying hypothesis? *Compend Contin Educ Pract Vet*. 2000;22(12):1108-1114.
8. Monnet E, Pelsue D, MacPhail C. Evaluation of laser Doppler flowmetry for measurement of capillary blood flow in the stomach wall of dogs during gastric dilatation-volvulus. *Vet Surg*. 2006;35(2):198-205.
9. Brourman JD, Schertel ER, Allen DA, Birchard SJ, DeHoff WD. Factors associated with perioperative mortality in dogs with surgically managed gastric dilatation-volvulus: 137 cases (1988-1993). *J Am Vet Med Assoc*. 1996;208(11):1855-1858.
10. Bebchuk TN, Hauptman JG, Braselton WE, Walshaw R. Intracellular magnesium concentrations in dogs with gastric dilatation-volvulus. *Am J Vet Res*. 2000;61(11):1415-1417.
11. Badylak SF, Lantz GC, Jefferies M. Prevention of reperfusion injury in surgically induced gastric dilatation-volvulus in dogs. *Am J Vet Res*. 1990;51(2):294-299.
12. Monnet E. Gastric dilatation-volvulus syndrome in dogs. *Vet Clin Small Anim*. 2003;33:987-1005.
13. Cornell K. Stomach. In: Johnston SA, Tobias KM, eds. *Veterinary Surgery: Small Animal*. 2nd ed. Elsevier Saunders; 2018:1700-1730.
14. Radlinsky MG. Surgery of the stomach. In: Fossum TW, ed. *Small Animal Surgery*. 3rd ed. Elsevier; 2013:485.
15. White RS, Sartor AJ, Bergman PJ. Evaluation of a staged technique of immediate decompressive and delayed surgical treatment for gastric dilatation-volvulus in dogs. *J Am Vet Med Assoc*. 2021;258(1):72-79.
16. Bruchim Y, Itay S, Shira BH, et al. Evaluation of lidocaine treatment on frequency of cardiac arrhythmias, acute kidney injury, and hospitalization time in dogs with gastric dilatation volvulus. *J Vet Emerg Crit Care*. 2012;22(4):419-427.
17. MacCoy DM, Sykes GP, Hoffer RE, Harvey HJ. A gastropexy technique for permanent fixation of the pyloric antrum. *J Am Anim Hosp Assoc*. 1982;18:763-768.
18. Ralph AG, Brainard BM. Update on disseminated intravascular coagulation: when to consider it, when to expect it, when to treat it. *Top Companion Anim Med*. 2012;27(2):65-72.
19. Cortegiani A, Ippolito M, Misseri G, et al. Association between night/after-hours surgery and mortality: a systematic review and meta-analysis. *Br J Anaesth*. 2020;124(5):623-637.
20. Cram P, Hillis SL, Barnett M, Rosenthal GE. Effects of weekend admission and hospital teaching status on in-hospital mortality. *Am J Med*. 2004;117(3):151-157.
21. Freemantle N, Richardson M, Wood J, et al. Weekend hospitalization and additional risk of death: an analysis of inpatient data. *J R Soc Med*. 2012;105(2):74-84.
22. Lilford RJ, Chen Y-F. The ubiquitous weekend effect: moving past proving it exists to clarifying what causes it. *BMJ Qual Saf*. 2015;24(8):480-482.
23. Green TI, Tonozzi CC, Kirby R, Rudloff E. Evaluation of initial plasma lactate values as a predictor of gastric necrosis and initial and subsequent plasma lactate values as a predictor of survival in dogs with gastric dilatation-volvulus: 84 dogs (2003-2007). *J Vet Emerg Crit Care*. 2011;21(1):36-44.
24. Israeli I, Steiner J, Segev G, et al. Serum pepsinogen-A, canine pancreatic lipase immunoreactivity, and C-reactive protein as prognostic markers in dogs with gastric dilatation-volvulus. *J Vet Intern Med*. 2012;26(4):920-928.
25. Goodrich ZJ, Powell LL, Hulting KJ. Assessment of two methods of gastric decompression for the initial management of gastric dilatation-volvulus. *J Small Anim Pract*. 2013;54(2):75-79.

SUPPORTING INFORMATION

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