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Original Research

Factors Affecting Survival and Future Foaling Rates in Thoroughbred Mares with Hydrops

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ABSTRACT

Prognosis for life and future fertility in broodmares following hydrops is reportedly good, but evidence to support these reports is limited. The objective of this case series was to describe the prognosis for survival and fertility in mares presented to a referral hospital following diagnosis of hydrops. Medical records were reviewed to identify mares diagnosed with hydrops. Data collected included history (gestation, sire of the foal), clinical findings at presentation and throughout hospitalization (complications, treatments, survival to discharge) and future foaling rates. Thirty mares were presented for hydrops between 2009 and 2019. Ninety percent (27/30) of mares survived (94.7% [18/19] hydrallantois, 75% [6/8] hydramnios) and 95% (20/21) of mares successfully had a future foal, of which 75% (15/21) had a foal the following year. There was no reoccurrence of hydrops. Mares managed with transcervical gradual fluid drainage demonstrated higher survival rate compared to those not managed with transcervical drainage (100% with vs. 78.6% without). The most frequent complications observed in mares that did not survive included hypovolemic shock ($n = 7$), hemorrhage ($n = 4$) and laminitis ($n = 3$). Complications observed in mares not returning to breeding included hypovolemic shock and hemorrhage. Causes of non-survival included peritonitis secondary to abdominal wall rupture or uterine tear, and tibial fracture. These results suggest that prognosis for survival and future fertility following a diagnosis of hydrops is good, provided the hydrops is diagnosed and treated appropriately with no damage to the reproductive tract or abdominal wall.

1. Introduction

Hydrops amnion and allantois are rare conditions in the horse, but are life-threatening medical emergencies. Hydrops is defined as the excessive accumulation of allantoic or amniotic fluid. This progressive condition develops over days to weeks with mares often presenting with a sudden onset of abdominal enlargement, painful ventral oedema, reluctance to walk, colic, anorexia, or body wall defects [1,2]. The information available based on a compilation of individual case reports suggests that affected mares are often multiparous (90.5%, 19/21), with a median age of 13 (4–19) years. Additionally, hydrops is usually diagnosed around 8.6 (range: 6.5–10) months of gestation, with 81% (17/21) diagnosed as hydrallantois and 19% (4/21) as hydramnios [2–11].

Early termination of pregnancy has historically been recommended in order to save the mare as foal survival is reportedly very unlikely. Untreated mares are at risk of life-threatening complications including abdominal wall injury (abdominal hernia, prepubic tendon rupture), uterine rupture, hypovolemic shock and/or dystocia [1,4–8,12].

Prognosis for survival of the mare is good if appropriate treatment is provided, and no complications develop [6–7,12]. Breeding prognosis and pregnancy rates are reported to be good if there is limited injury to the reproductive tract, but limited information is available. Previous reports indicate that 71% (15/21) of mares survived following hydrops, with 14% (3/21) being rebred, and a single

Abbreviations: AWR, Abdominal Wall Rupture; PUD, Premature Udder development; CTUP, Combined Thickness of the Uterus and Placenta; GTD, Gradual Transcervical Fluid Drainage; NSAIDs, Non-Steroidal Anti-Inflammatories; RFM, Retained Fetal Membranes.

The cases presented in this retrospective study were treated at Hagyard Equine Medical Institute in Lexington, Kentucky, USA.

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mare successfully back in foal the same year. Reoccurrence in subsequent pregnancies is reported but rare [4].

Limited studies have reported the role of genetics [6,11]. In a collection of 21 cases of hydrops described over 22 years (1986–2018), breeds represented were Thoroughbreds (33% [7/21]) and Standardbreds (14% [3/21]), although a variety of other breeds have been reported [3–11]. In one study, two Shetland pony mares presented with hydrops after being bred to the same stallion, suggesting heritability [6].

There are relatively few reports on the outcomes (survival and future foaling rates) of mares with hydrops, and the number of reported cases is small. The objectives of this study were to describe the survival rate of mares presenting to a referral hospital with hydrops, and to describe the prognosis for return to breeding and foaling following management of hydrops.

2. Material and methods

2.1. Data collection

Medical records of pregnant mares admitted to Hagyard Equine Medical Institute (Lexington, Kentucky) from 2009 to 2019 were reviewed. Inclusion criteria included confirmed diagnosis of hydrops (allantois or amnios) by transrectal palpation and transrectal and/or transabdominal ultrasonography. On transrectal palpation, hydrops was suspected with the presence of a dome-shaped tight uterus preventing ballottement of the fetus. Hydrallantois was suspected if the dorsal wall of the uterus was protruding above the level of the pubis, and hydramnios was suspected otherwise. On transrectal and/or transabdominal ultrasound, hydrallantois was diagnosed by the presence of excessive allantoic fluid with depths $>$18 cm (normal range: 13.4 $\pm$ 4.4 cm) [14]. Hydramnios was diagnosed as the presence of turgid amnion without the normal undulating appearance and excess fluid (normal range: 7.9 $\pm$ 3.5 cm) [14].

Data collected included age, breed, parity, gestational length, clinical signs at presentation, and characterization of the hydrops (amnios, allantois). A review of all records was performed to collect information regarding the therapeutic approach (intravenous fluid therapy, gradual fluid drainage), the volume of fetal fluid retrieved, incidence of complications following delivery, and outcome (discharged, euthanized). Laboratory analysis (complete blood count, serum biochemistry) during hospitalization was also reviewed. Foaling rates were investigated by recording hospitalized foals born from hydropic mares in the years following management of hydrops from the medical record system at the institution of study database, and through the online database equibase.com. “Back in foal” was defined as a mare producing a live foal any year following the hydropic pregnancy, and “back in foal the same year” defined mares successfully bred back the same year following the hydropic event, and delivering a live foal the following year. Stallions bred to the mare during the year for which the mare experienced a hydropic pregnancy were identified using the online database equineline.com. Fetal and placental abnormalities were identified using necropsy reports from the University of Kentucky Veterinary Diagnostic Laboratory when available.

2.2. Data analysis

Statistical analysis was performed using SAS 9.4 using varying models depending on the data. Normal distribution of continuous variables was assessed by density plot and Q-Q plot, with normality assessed using a Shapiro-Wilk test. While age, volume of fluid retrieved, creatinine concentration and white blood cell count at admission were normally distributed, other continuous variables (gestation length, packed cell volume, total protein count, creatine kinase concentration) were not normally distributed (Supplementary 1). Thus, all parameters were reported as median and range. Association between gradual transcervical fluid drainage (GTD) and survival, GTD and future foaling rate, GTD and complications, complications and future foaling rate, type of hydrops and occurrence of dystocia, and GTD and dystocia were determined using a Chi-square or Fisher’s exact test using 2 $\times$ 2 frequency tables. In instances where cell counts were equal to zero, one was added to each cell. Odds ratio (OR) and 95% confidence interval (95% CI) were calculated from the 2 $\times$ 2 frequency tables. Odds ratios >1 or <1 with 95% CI excluding 1 with a corresponding $P < 0.05$ were considered significant. Odds ratios = 1 indicated absence of association between the risk factor and outcome.

3. Results

3.1. Animals

From 2009 to 2019, 30 mares with a median age of 14.5 (4–21) years were managed for hydrops at Hagyard Equine Medical Institute (Lexington, KY). None of the mares meeting the inclusion criteria were excluded for other reasons. Thoroughbreds were overrepresented (93.3%; 28/30), and other breeds included one Standardbred and one Saddlebred. Ninety-seven percent (28/30) of mares were multiparous (parity was unknown for two mares). The same stallion was used in two mares but not during the same year (one in 2017 and one in 2019). A different stallion was used for the remaining 26 mares for which the information was available. Median gestation length at time of diagnosis of hydrops was 298.5 (175–360) days. Mares presented with 0 to 6 concurrent clinical signs, including an enlarged abdomen, discomfort, premature udder development, anorexia, vaginal discharge and ventral oedema (Table 1 and Fig. 1). Thirty-seven percent (11/30) of mares were presented with placental abnormalities based on ultrasonographic findings (increased combined thickness of the uterus and placenta (CTUP) as previously described [15], abnormal fetal biophysical profile) at admission (6/11, 54.5%) and/or had been treated for presumed placentitis prior to presentation for hydrops (6/11, 54.5%).

Abnormal hematology and biochemistry results were nonspecific, suggesting systemic complications, and included dehydration (median PCV: 46.6%; 22.4–51.8), leukocytosis or leukopenia (median white blood cell: $10.35.10^3$/µL; 6.2–15.0), hyper- or hypoproteinemia (median TP: 6.5 g/dL; 3.9–7,7) and elevated creatine kinase (median CK: 316,55 IU/L; 80–1705) (Individual patient data available in Supplementary Table S1).

3.2. Diagnosis

Characterization of the type of hydrops was not successful in four mares. Of the remaining 26, 73% (19/26) were diagnosed with hydrallantois and 31% (8/26) with hydramnios. One mare (case 15) was diagnosed with both hydrallantois and hydramnios. There was no change in the diagnostic techniques used to diagnose hydrops over the study period.

3.3. Management of hydrops

Fifty percent (15/30) of mares were managed by GTD of the excessive fluid prior to abortion. Drainage was performed as previously described [14]. Briefly, under sedation and after sterile preparation, the cervix was manually dilated and the mucus plug removed. A 12 Fr or 14 Fr sharp tipped trocar was then used to penetrate the chorioallantoic (and amnion) membranes. A small sterilized stomach tube was then placed through the trocarized membrane(s) to gradually drain fluids over 1 to 2 hours depending on

Table 1
Case description of presenting clinical signs (CS) and fetal survival.

Gestation				Clinical Signs							Parturition			Fetal Outcome		
Case	Age (Years)	Gestation Length(Days)	Type of Hydrops	Distended Abdomen	Discomfort	Premature Udder Development	Anorexia	Vaginal Discharge	Ventral Oedema	Total Number of CS	Spontaneous	Assisted Vaginal	C-section	Stillbirth	Euthanasia	Discharged
1	16	260	Am	+						2	+				+	
2	14	299	Am	+			+			3		+		+		
3	16	285	Al			+			+	3	+				+	
4	7	295	Am		+					1		+		+		
5	-	175	-					+		1		+		+		
6	13	310	Al	+					+	3		+		+		
7	-	339	Al	+	+		+			3		+			+	
8	18	280	Am	+						2	+				+	
9	13	-	Al	+						2		+		+		
10	19	280	Al	+				+		2	+			-	-	-
11	15	310	Al	+		+				3	+				+	
12	7	298	Al	+		+			+	3	+				+	
13	15	250	Al	+						2		+		+		
14	8	281	Al	+		+				3		+		+		
15	12	280	Al/Am	+		+				2	+			+		
16	4	210	Al					+		1		+		+		
17	19	260	Al	+				+		3		+		+		
18	14	300	Al	+	+		+	+	+	6	+					Yes
19	21	320	Am		+		+			2		+		?	?	No
20	17	310	Al		+		+	+		3	+				+	
21	19	313	Al	+		+				2		+				Yes
22	15	250	Al		+		+			3	+			+		
23	12	360	Am							0			+		+	
24	12	325	Al	+						1	+					Yes
25	14	318	Al							0					Death	
26	15	306	Al	+	+	+				4		+			+	
27	16	330	Am	+	+				+	4			+	+		
28	20	338	Al	+	+					3		+			Death	
29	14	269	-							0		+		+		
30	12	-	-	+			+			2	+			?	?	No
Total				20	9	7	7	6	5		12	16	2	13	11	3

Abbreviations: Am, amnios; Al, allantois.

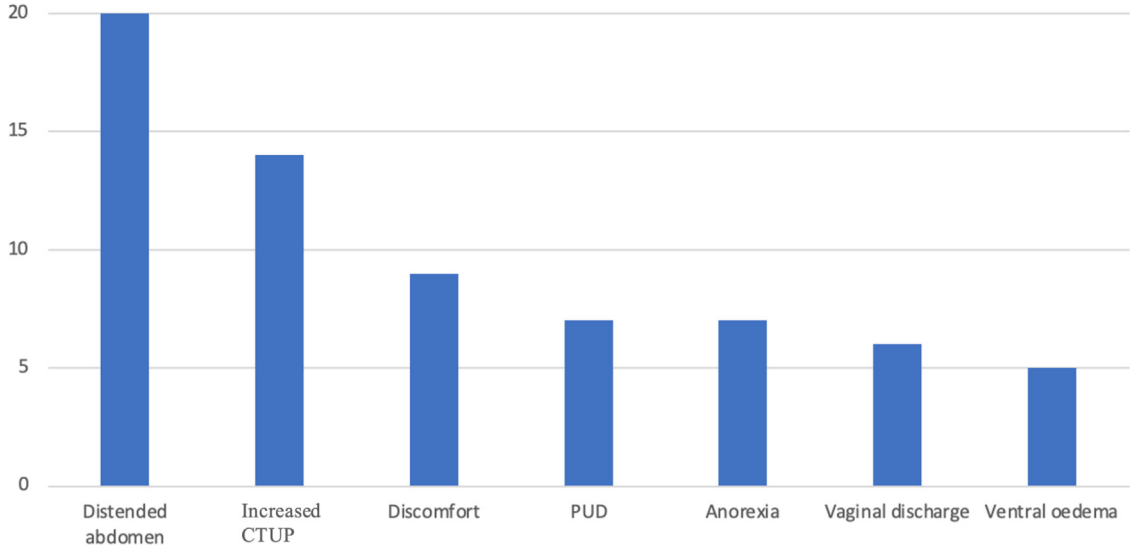

Fig. 1. Clinical signs at time of presentation ($n = 30$).
CTUP, combined thickness of the uterus and placenta; PUD, premature udder development.

the volume of fluid to be drained. The volume of fluid drained was reported for only 11 mares and ranged from 20 to 189 liters (median: 85 L). Reasons for not performing GTD were not reported but most likely included mares presenting with hydrops close to term, prompting attempts to prolong the pregnancy in order to save the foal, mares being managed and foaling at the farm, or mares hospitalized for assisted delivery without gradual fluid drainage for financial limitations.

Eighty percent (24/30) of mares were administered intravenous fluid therapy. All treated mares received isotonic fluids (23/24 Plasmalyte and 1/24 Lactated Ringers). One mare with endotoxemia received synthetic colloids and two hemorrhaging mares (cases 23 and 27) were treated with plasma and whole blood (Individual data are available in Table S2). Eighty-seven percent (26/30) of mares received non-steroidal anti-inflammatories. All treated mares received flunixin meglumine (0.5–1.1 mg/kg iv, sid or bid). One mare was given phenylbutazone (2 mg/kg iv bid) and one mare was given firocoxib (0.2 mg/kg po sid). Eighty-three percent (25/30) of mares were treated with antimicrobials, which most commonly involved a combination of trimethoprim-sulfonamides (30 mg/kg po bid) (5/25) or penicillin (22000 IU/kg iv qid) (19/25) with gentamicin (6.6 mg/kg iv sid) (24/25). One mare was treated with oxytetracycline (7.5 mg/kg iv sid), and one mare received enrofloxacin (7.5 mg/kg iv sid).

Time from drainage to parturition was recorded for 13 mares and ranged from less than 1 hour to 28 hours (median: 16 hours). Sixty percent (18/30) of mares experienced dystocia requiring assisted vaginal delivery (16/18; 88.9%) or caesarian section (2/18; 1.1%). Of the mares with dystocia, 69% (11/16) had hydrallantois and 31% (5/16) had hydramnios (type of hydrops was not recorded for two mares), but there was no significant association between the type of hydrops (hydrallantois or hydramnios) and occurrence of dystocia (OR = 0.73; 95% CI, 0.16, 4.0: $P > 0.99$). Fifty percent (9/18) of mares with dystocia were treated with GTD, and there was no significant association between GTD and occurrence of dystocia (OR = 1.0; 95% CI, 0.24, 4.2: $P > 0.99$).

Complications following delivery included metritis, retained fetal membranes (RFM), intestinal impaction, endotoxemia, hypovolemic shock, reproductive tract or intra-abdominal hemorrhage and laminitis (Table 2 and Fig. 2). Two mares (cases 27 and 28) developed abdominal wall rupture, one of which developed peritonitis (case 27). One mare (case 25) had a uterine tear and developed peritonitis (Fig. 2). There was no significant association between GTD and presence of complications (OR = 3.2; 95% CI, 0.46, 18.3: $P = 0.390$).

Ninety percent (27/30) of mares survived to discharge following hydrops. Survival rate was higher in mares with hydrallantois (94.7%, 18/19) than hydramnios (75%, 6/8), but here was no significant association between the type of hydrops and survival (OR = 0.26; 95% CI, 0.26, 391.5: $P = 0.19$).

Type of hydrops was not documented in 4 mares, which all survived. Most mares developed multiple complications, and non-surviving mares (cases 23, 25 and 27) had the highest frequency of complications, but there was no significant association between the presence of complications and survival (OR = 1.0; 95% CI, 0.1, 71.5: P >0.99).

All 15 mares treated with GTD survived regardless of the type of hydrops, while only 78.6% (11/14) of mares managed without GTD survived (Table 3 and Fig. 3). One mare (case 15) presented with both types of hydrops, and survived without GTD. However, there was no significant association between performing GTD and survival of the mares (OR = 4.9; 95% CI, 0.63, 63.4; $P = 0.355$). Table 4 summarizes the effect of complications on survival and future foaling rates.

Of the three mares that did not survive, one mare had a tibial fracture during recovery following emergency caesarean section (case 23), one mare had a uterine tear following delivery resulting in peritonitis and laminitis (case 25), and one mare had an abdominal wall tear following caesarean section leading to peritonitis and small intestinal evisceration (case 27).

Gross pathology and histopathology of the placenta were available in 11 cases and are reported in Table 5. Two mares (cases 8 and 11) initially diagnosed with an increased CTUP at admission showed no placental abnormality on pathology. Conversely, two mares in which no placental abnormality was diagnosed during pregnancy demonstrated significant pathological changes of their placenta (cases 12 and 16).

Fifty-eight percent (14/29) of foals were born alive, 64% (9/14) of which were euthanized shortly thereafter due to poor prognosis and two died during hospitalization. Stillbirth was observed in 13/29 (44,8%) cases. Foal survival to discharge was 10.3% (3/29), with one foal euthanized at one month of age of unknown reasons (Table 1). Foal survival to discharge was unknown for one mare (case 10). Prematurity (gestational length < 320 days) was

Table 2
Case description of complications, survival and return to breeding.

Case	Complications											Mare Survival	Back in foal
	Hypovolemic shock	Abdominal Wall Rupture	Hemorrhage	Peritonitis	Retained Fetal membranes	Metritis	Intestinal impaction	Endotoxemia	Uterine tear	Laminitis	Total Number		
1					+						1	Yes	?
2						+	+				2	Yes	Yes
3					+	+					2	Yes	Yes
4					+	+	+	+			4	Yes	Yes
5											0	Yes	?
6											0	Yes	Yes
7					+	+	+				3	Yes	?
8					+						1	Yes	Yes
9						+	+	+			3	Yes	Yes
10											0	Yes	Yes
11					+	+		+			3	Yes	Yes
12					+	+	+	+		+	5	Yes	Yes
13					+		+	+		+	4	Yes	Yes
14	+					+	+	+			4	Yes	Yes
15	+					+	+				3	Yes	?
16											0	Yes	Yes
17	+				+	+	+	+			4	Yes	No
18											0	Yes	Yes
19						+		+			2	Yes	?
20			+			+					2	Yes	Yes
21					+	+	+				3	Yes	Yes
22					+	+					2	Yes	Yes
23	+		+								2	No	-
24						+					1	Yes	Yes
25	+		+	+	+	+		+	+	+	8	No	-
26											0	Yes	Yes
27	+	+	+	+	+	+	+				7	No	-
28		+			+	+					3	Yes	?
29					+						1	Yes	Yes
30	+				+	+					3	Yes	Yes
Total	7	2	4	2	16	19	11	9	1	3		27	20

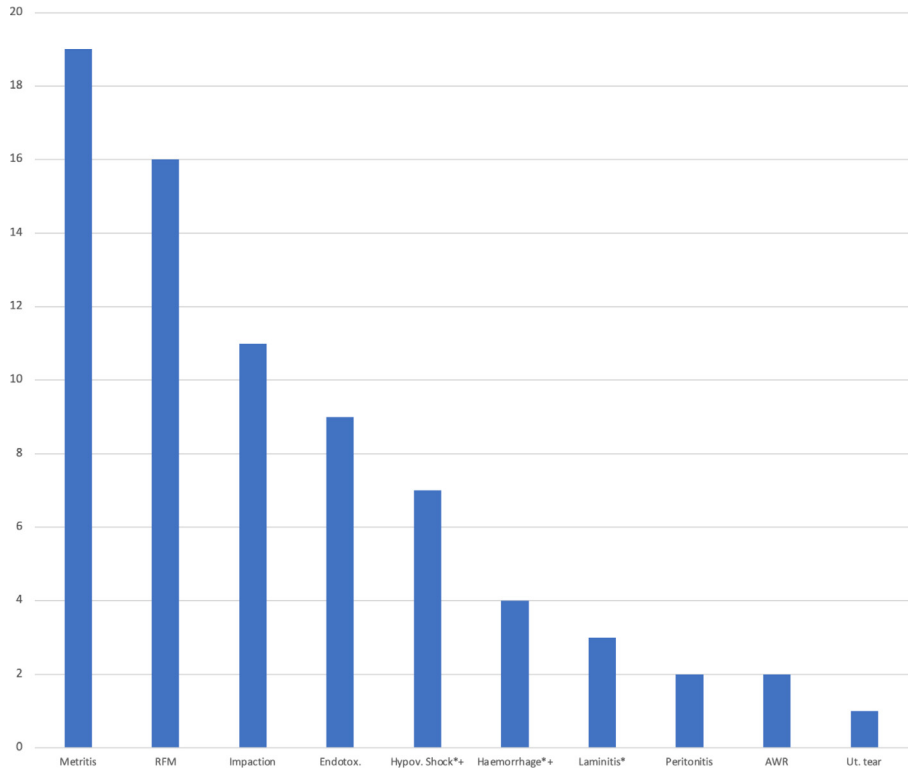

Fig. 2. Complications following hydrops (n = 28). Hypovol., hypovolemic shock; AWR, abdominal wall rupture; RFM, retained fetal membranes; Endotox., endotoxemia; Ut. Tear, uterine tear.

Table 3
Effect of treatments on survival and foaling rates.

			Survival Rate		Foaling Rate		Foaling Rate Next Year	
	n	%	Yes	No	Yes	No	Yes	No
IV fluids								
With	24/30	80	21/24	3/24	15/17[a]	2/17[a]	11/15	4/15
Without	6/30	20	6/6	0/6	5/5	0/5	4/5	1/5
Gradual fluid drainage								
With	15/30	50.0	15/15	0/15	12/13[a]	1/13[a]	8/13	5/13
Without	15/30	50.0	12/15	3/15	8/8	0/8	7/8	1/8
Antibiotics								
With	25/30	83.3	22/25	3/25	15/16[a]	1/16[a]	11/15	4/15
Without	5/30	16.7	5/5	0/5	5/5	0/5	4/5	1/5
Anti-inflammatories								
With	26/30	86.7	23/26	3/26	16/1[a]	1/17[a]	12/16	4/16
Without	4/30	13.3	4/4	0/4	4/4	0/4	3/4	1/4

[a] Information was not available for all surviving mares.

Table 4
Effect of complications on survival and foaling rates.

			Survival Rate		Foaling Rate		Foaling Rate Next Year	
	n	%	Yes	No	Yes	No	Yes	No
Hypovolemic shock	7/30	23.3	4/7	3/7	2/3[a]	1/3[a]	1/2	1/2
Abdominal wall rupture	2/30	6.7	1/2	1/2	0/1	1/1	-	-
Hemorrhage	4/30	13.3	1/4	3/4	1/1	0/1	1/1	0/1
Peritonitis	2/30	6.7	0/2	2/2	-	-	-	-
Retained fetal membranes	16/30	53.3	14/16	2/16	10/11[a]	1/11[a]	8/10	2/10
Metritis	19/30	63.3	17/19	2/19	12/13[a]	1/13[a]	10/12	2/12
Intestinal impaction	11/30	36.7	10/11	1/11	7/8[a]	1/8[a]	5/7	2/7
Endotoxemia	9/30	30.0	8/9	1/9	6/7[a]	1/7[a]	4/6	2/6
Uterine tear	1/30	3.3	0/1	1/1	-	-	-	-
Laminitis	3/30	10.0	2/3	1/3	2/2	0/2	1/2	1/2

[a] Information was not available for all surviving mares.

Table 5
Placental and fetal abnormalities.

Case	Increased CTUP	Hydrops	Fetal Outcome		Fetal Gross Pathology						Placental Histopathology						
			Stillbirth	Euthanasia	Umbilical Torsion	E coli septicemia	Pneumonia	Decreased Bone formation	Meconium Amnionitis	Other	Villi	Stroma	Vessels	Hyperplasia/ cysts	Inflammation	Pathogens	No lesion
1		Am		+		+											
2	+	Am	+		+	+	+			*Actinobac.* septicemia	Mineral.	Thick.	Mineral.	Metaplasia	Al + Am	Funisitis, *Actinobac.*	
3	+	Al		+							Necr., mineral.	Fibr., hemor. (separation)	Dilation			Nonpath.	
4		Am	+													Mixed (autolyzed)	
5		-	+						+	Facial malformation, hydrocephalus							
6		Al	+			+					Atrophy	Thick., edema		Fibroplasia, hyperplasia		*E coli, Strept α-hemolytic*	
7		Al		+		+	+										
8	+	Am		+													+
9		Al	+									Edem,				*Enterobacter, Pseudomonas*	
10		Al	-	-													
11	+	Al		+													+
12		Al		+			+		+	Metatarsal fracture	Necr.	Fibr., Am meconium, edema		Hyperplasia		Nonpath.	
13		Al	+		+	+	+				Thick.	Fibr., edema (Al +Am)	Sclerosis, fibr. thick.			Bacilli	
14	+	Al	+			+	+										
15	+	Al/ Am	+								Necr.	Fibr. (al + am)		Cysts		Nonpath.	
16		Al	+								Thick.	Am edema, Al mineral.	Mineral.			Nonpath.	
17	+	Al	+							Leptospirosis							
18	+	Al															
19		Am	?	?													
20		Al		+			+	+									
21		Al															
22	+	Al	+														
23		Am		+		+	+										
24		Al															
25		Al		D													
26	+	Al		+			+	+									
27		Am	+														
28		Al		D													
29		-			+												
30	+	-		?													
Total	11			11	3	7	8	2	2								

Abbreviations: Actinobac., actinobacillus; Am, Amnios; Al, allantois; CTUP, combined thickness of the uterus and placenta; D, spontaneous death; ; Fibr., fibrosis; hemorrh., hemorrhagic; Mineral., mineralization; Necr., necrosis; Nonpath., nonpathologic; Strept., Streptococcus; Thick., thickening.

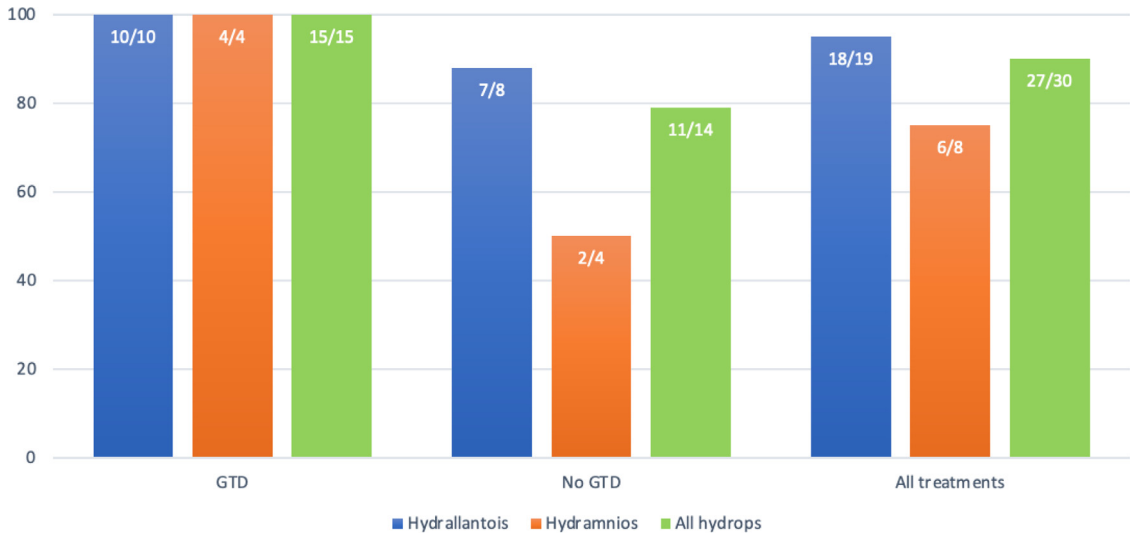

Fig. 3. Survival to discharge depending on the type of hydrops and treatment (%).
GTD, gradual transcervical fluid drainage.

observed in 22/28 (78.6%) cases for which the information was available. Median gestational length leading to live foal birth was 310 (260–360) days, and 274.5 (175–330) days for foals born dead. Fetal pathologies are presented in Table 5.

3.4. Breeding and foaling rates

Information regarding return to breeding was available for 21 out of the 27 surviving mares. Ninety-five percent (20/21) of mares successfully had a future foal with 75% (15/21) of mares delivering a live foal the year following management of hydrops (Table 2 and 4). Reasons for one mare not bred was unknown. There was no reoccurrence of hydrops in this study. There was no significant association between performing GTD and future foaling rate (OR = 0.72; 95% CI, 0.05, 7.0; $P > 0.99$), or between the presence of complications and future foaling rate (OR = 0.75; 95% CI, 0.08, 12.5: $P > 0.99$).

4. Discussion

This study describes cases of hydrops in detail, focusing on mare survival and reproductive prognosis. The survival rate following hydrops in this study was good, with 90% of mares surviving to discharge. Proportion of successful foaling after management of hydrops in the study population was relatively high, with 95% of mares successfully producing a live foal in the future, including 75% of mares delivering a live foal in the immediate year following the hydropic event.

While the occurrence of hydrops in mares remains rare based on our findings (30 cases of hydrops out of 89,184 live foals registered in Kentucky during the study period (jockeyclub.com)), the current study showed a much higher incidence than previously reported, and could indicate a better understanding and improved diagnosis of hydrops over the last decade from both veterinarians and owners, or an increase in the occurrence of hydrops in recent years for unknown reasons.

Mares included in the study represented the population described in the literature, with the majority being adult, multiparous mares in their last trimester of gestation. Presenting clinical signs included a distended/enlarged abdomen and discomfort as the most frequent, consistent with previous studies.

4.1. Hydrops allantois vs. hydrops amnios

Excessive fluid accumulated more frequently in the allantoic compartment than in the amniotic compartment, but with a less drastic difference than previously described (hydrallantois in 90% compared to hydramnios in 10% of the cases [1,4,8,12]). Additionally, one mare was diagnosed with hydrops of both compartments. The limited clinical ability to differentiate between hydrallantois and hydramnios may have led to mis-categorization, as no difference in diagnostic technique was observed over time and between mares.

Discrepancies were detected between ultrasonographic findings and histopathology of placentas. In five cases, hydrallantois or hydramnios was diagnosed by ultrasonography, while characteristic lesions were found in the other or both compartments on histopathology. This suggests that ultrasonography lacks specificity for differentiating type of hydrops and supports the difficulties in confirming a definitive diagnosis. Interestingly, for two mares in which increased CTUP was identified ultrasonographically, there was no histopathological evidence of placental abnormality. These findings highlight the limitations of diagnosis of placental abnormalities and hydrops with the current diagnostic tools available (transabdominal and transrectal ultrasound) without analysis of fetal fluids, and indicates that additional biomarkers would be helpful.

Hydramnios has previously been associated with fetal abnormalities, however in our study, only one case of fetal abnormality was identified. Necropsy results were not available for a large number of foals, limiting identification of the relationship between hydramnios and fetal abnormalities.

Placentitis has previously been associated with hydrops, but its implication in the development of hydrops remains unknown. Similar to previous reports, placental abnormalities were reported in the current study but few inflammatory cells were detected from hydrallantoic placentas [2–11,13]. Whether placentitis is often misdiagnosed in cases of hydrops due to the similar presenting signs (premature udder development, placental changes, etc), or underdiagnosed in the occurrence of falsely normal CTUP secondary to overstretching is unknown. The etiology and pathogenesis of hydrallantois is currently under investigation but has not been clearly identified [13]. Dini *et al* identified vascular changes associated with hydrallantois. Capillary density in chorionic villi was signifi-

cantly lower in hydrallantoic placenta samples, and was associated with abnormal expression of angiogenic and hypoxia-associated genes, leading to tissue hypoxia and oedema [4,6,12,15]. While this suggests hypoxemia as a common pathway for the observed alterations of placental tissues, multiple factors may be involved. In our study, a limited number of placental pathology reports were available, however changes were similar to previous studies and characterized by stromal oedema and fibrosis. A similar pathogenesis leading to hydramnios and hydrallantois could therefore be surmised. Further studies involving a larger sample size, with diagnosis of types of hydrops and associated pathological changes are warranted.

4.2. Management of hydrops and survival

The results of this study suggest that although not statistically significant, dystocia appears to occur more frequently after diagnosis of hydrallantois than hydramnios, and overall, a large number of mares presented with dystocia. While the reason for this higher prevalence with hydrallantois is unknown, occurrence of dystocia was expected as uterine inertia is a known consequence of prolonged stretching of the uterus in cases of hydrops [1,5,8].

Proportion of surviving mares increased when gradual fluid drainage was performed, but there was no significant effect of performing GTD on survival. Limited data prevented identification of correlations between the severity of hydrops (volume of fetal fluid, hypovolemic status) and survival with or without GTD, and highlights the importance of defining criteria for performing gradual fluid drainage.

Non-survival was secondary to trauma to the abdominal, reproductive or musculoskeletal system. Although the single mare dying from abdominal wall rupture and evisceration was most likely a surgical complication, occurrence of hydrops may have weakened the abdominal musculature and contributed to the development and the severity of this complication. The two mares which underwent caesarian sections were euthanized due to severe complications. This might suggest that surgical intervention in mares with hydrops should be avoided if possible. However, due to the very low number of caesarian section cases, this requires cautious interpretation. The majority of mares were administered a combination of anti-inflammatories and antibiotics, with aggressive fluid therapy assumed to be beneficial for preventing hypovolemic shock and other severe complications. These findings suggest that hydrops is a critical condition which requires aggressive medical management, including GTD, to improve maternal viability and prevent severe, life-threatening complications. Foal survival rate remains very poor and prolonging pregnancy to save the foal appears undesirable.

4.3. Breeding and foaling rates

Future foaling rates were found to be excellent, with successfully breeding a mare during the same year depending on the type of complication, and timing during the breeding season. Although not statistically significant, severe complications, such as hypovolemic shock and hemorrhage were observed in mares failing to get back in foal. Whether these mares failed to conceive as a consequence of these complications or breeding was not attempted was not investigated in our study. None of the treatments appeared to affect the ability to produce a foal.

The survival and foaling rates of the current study are relatively higher than those reported in previous studies (71.5% and 14%, respectively [2–11]). This suggests better recognition and management improves viability and prevents damage to the reproductive tract. This is further illustrated by the high foaling rates after rebreeding during the same season as the hydropic event.

Reoccurrence of hydrops was not identified in this study. However, due to the retrospective nature of the study, it was difficult to identify information on some mares that may have been transported to other geographical areas or were presented to other veterinary centers in subsequent years.

While no breed predisposition to hydrops has been described in the literature, majority of mares were Thoroughbreds in our study [7]. As Hagyard Equine Medical Institute (Lexington, KY) experiences a high case-load of Thoroughbred broodmares compared to other breeds, no breed predisposition can be inferred based on this data. A paternal influence on the altered expression of angiogenic genes is suspected in the pathogenesis of hydrops, especially hydrallantois but further elucidation is needed [6,13]. Heritability could not be demonstrated in this study, as none of the mares presented to our practice more than once for hydrops, and a different stallion was used in all mares except two. Further investigation including a large-scale, multi-center study with different breeds with a description of the pedigree of the dam and stallion over several generations is required.

5. Limitations

The limitations of the current study include the retrospective nature, and small sample size. A priori sample size was not calculated as this was a convenience sample. The small number of cases, although representative of the rarity of the condition, was not appropriate for performing multivariable statistical analysis. However, most mares presented with multiple clinical signs and/or complications, which precluded the possibility of drawing meaningful conclusions due to the absence of adjustment for confounding variables. While normal fluid depth measurements were previously published, diagnosis of hydrops by ultrasonography remains subjective and differentiation between hydrallantois and hydramnios can be challenging, unless the fluid is analyzed [16]. In their study, Bucca et al did not evaluate the effect of breed on fluid depth, and different reference ranges might exist for Thoroughbred mares [16]. The development of a scoring system assessing the severity of hydrops may help identify indication for GTD.

6. Conclusion

Hydrops is a rare condition in horses, with a good prognosis for life and reproductive ability if timely aggressive medical management is performed. Treatment with GTD may allow improved survival and prevent severe complications, and is recommended. The results of this report suggest that mares can be bred-back during the same year and deliver normal foals.

Authors' contributions

Conceptualization: L.L., K.W., and R.B. Methodology: L.L., K.W., and R.B. Formal analysis: L.L., C.F., and M.C. Investigation: L.L. and N.K. Resources: K.W. and R.B. Writing – original draft: L.L. Writing – review and editing: L.L., K.W., C.F., M.C., and R.B. Visualization: L.L. Supervision: K.W. and R.B.; Project administration: K.W. and R.B.

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Supplementary materials

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