Long-Term Outcome After Surgical Ameroid Ring Constrictor Placement for Treatment of Single Extrahepatic Portosystemic Shunts in Dogs

Emily L. Falls¹, DVM, Milan Milovancev², DVM, Diplomate ACVS, Geraldine B. Hunt³, BVSc, MVCS, PhD, FACVS, Leticia Daniel⁴, MV, Margo L. Mehl⁵, DVM, Diplomate ACVS, and Chad W. Schmiedt¹, DVM, Diplomate ACVS

¹ Department of Small Animal Medicine and Surgery, College of Veterinary Medicine, University of Georgia, Athens, Georgia, ² Department of Clinical Sciences, College of Veterinary Medicine, Oregon State University, Corvallis, Oregon, ³ Department of Veterinary Surgical and Radiological Sciences, University of California, Davis, California and ⁴ VCA-San Francisco Veterinary Specialists, San Francisco, California

Corresponding Author
Dr. Milan Milovancev, DVM, Diplomate ACVS, 267 Magruder Hall, Oregon State University, Corvallis, OR 97331. E-mail: milan.milovancev@oregonstate.edu

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Objective: To report long-term clinical outcome in dogs treated for single congenital extrahepatic portosystemic shunt (CEHPSS) with an ameroid ring constrictor (ARC) and to identify perioperative variables associated with outcome.

Study Design: Retrospective, multi-institutional study.

Animals: Dogs (n = 206) with CEHPSS.

Methods: Medical records of dogs with CEHPSS treated by ARC were reviewed for perioperative and short-term (<1 month) data. Long-term follow-up information was obtained by telephone interview with referring veterinarians and/or owners. Kaplan–Meier analysis was used to estimate median survival time. Factors associated with short-term survival, outcome grade, and total survival time were identified.

Results: Fifteen dogs died <1 month after ARC placement. Follow-up data were obtained for 112 of 191 dogs that survived >1 month; median follow was 54 months (range, 1–175 months) and 103 (92%) dogs had no clinical signs. Estimated median survival time was 152 months. Variables significantly associated with short-term survival included being intact and a low total white blood cell (WBC) count. Variables significantly associated with a successful outcome included having surgery later in the study period and negative postoperative nuclear scintigraphy. In the long-term survival analyses, intact dogs and those with higher WBC counts and occlusion pressures and lower bile acid concentrations were more likely to survive.

Conclusions: Dogs with CEHPSS treated by ARC generally have a good prognosis and prolonged postoperative survival.

Canine portosystemic shunts are anomalous vascular connections between the portal and systemic venous systems. The abnormal communication permits a proportion of the blood returning from the portal organs to bypass the liver and flow directly into the systemic circulation. Congenital extrahepatic portosystemic shunts (CEHPSS) result from abnormal embryologic development of the abdominal vasculature and are the most common type of portosystemic shunt.¹–⁴ CEHPSS primarily occur in miniature and toy breed dogs and are hereditary in some breeds.⁵,⁶ Clinical signs associated with CEHPSS occur because of decreased hepatic blood flow and the resultant impairment of normal hepatic metabolic functions. Typical clinical signs include polyuria, polydipsia, ammonium biurate cystolith formation, vomiting, diarrhea, and hepatic encephalopathy.¹,²,⁷,⁸

The goal of treatment for CEHPSS is to restore normal hepatopetal blood flow, reestablish normal hepatic metabolic function, and resolve clinical signs. Dogs with CEHPSS may be managed medically; however, medical treatment often fails to completely eliminate clinical signs, and survival after surgical treatment is significantly longer than survival after medical treatment.¹⁹ A variety of surgical techniques have been described for occlusion of CEHPSS including suture ligation, ameroid ring constrictor (ARC) placement, cellophane banding, hydraulic occluder placement, and intravascular techniques.¹⁰ Surgical CEHPSS treatment by ARC placement remains a popular technique.¹¹ ARC theoretically provides for a gradual attenuation of the shunting vessel, allowing for hepatic accommodation of increasing portal blood flow and preventing development of portal hypertension. However, more recent studies document a delayed acute occlusion potentially resulting from inflammation followed by fibrosis and thrombosis.¹²,¹³

Mehl et al.⁷ reported postoperative mortality of 7.1% after ARC placement for CEHPSS in 168 dogs with predictive factors for death being high preoperative total white blood cell
(WBC) count and occurrence of seizures or abdominal distension postoperatively. Outcome data was obtained in 108 dogs with a median follow-up time of 3 years. Of those dogs, 80% had an excellent outcome (lack of clinical signs without concurrent medical management). Perioperative factors associated with an excellent outcome included: high serum albumin concentration, low total WBC count, lower temporary test occlusion portal pressure, absence of postoperative seizures, and absence of continued postoperative shunting.

Given that CEHPSS treatment is often performed at a young age and ARC treatment has been available for over a decade, longer follow-up times are now available in a cohort of dogs with relatively uniform treatment methods. Thus, we can examine and report the success of treatment over the lifespan of affected dogs and determine long-term prognosis and perioperative factors significantly associated with outcome. Our specific aims were to expand upon the previous report\textsuperscript{7} by: (1) investigating clinical outcome of a larger group of dogs treated with an ARC for a single CEHPSS over a longer time period and (2) to identify perioperative variables significantly associated with outcome. We hypothesized that most dogs with CEHPSS treated with an ARC will have excellent long-term outcome and that the perioperative factors found to be significantly associated with outcome in the previous study would remain significant in the current study.

**MATERIALS AND METHODS**

**Study Population**

Dogs surgically treated for a single CEHPSS by ARC placement at the University of Georgia (UGA), University of California-Davis (UCD), and North Carolina State University (NCSU) between 1995 and 2001 were included. A subset of this population (those dogs treated at UCD and NCSU) have previously had postoperative outcomes reported with a median follow-up of 3 years,\textsuperscript{7} but were included here as their follow-up times have increased substantially and there were dogs in that cohort that were previously lost to follow up that have since been identified. Diagnostic, surgical, and postoperative treatment methods adhered to the current standard-of-care and have been detailed previously.\textsuperscript{7}

**Medical Records Review**

Data extracted from the medical records included breed (categorized as Yorkshire Terrier, Miniature Poodle, Maltese, Miniature Schnauzer, Shih Tzu, Pug, or “other”), age, sex, and body weight at time of surgery. Presence of clinical signs of hepatic encephalopathy (mental dullness, inappropriate mention, ataxia, head pressing, star gazing, and/or seizures) before surgery was recorded. Preoperative total WBC, serum albumin concentration, and pre- and postprandial bile acids concentrations (BA) were recorded.

Intraoperative information extracted from the medical records included shunt location (portocaval if it entered the abdominal vena cava or portoazygous if it crossed through the crus of the diaphragm or esophageal hiatus), temporary test occlusion portal pressure, the difference in portal pressure between baseline and after temporary test occlusion of the shunt vessel, and the final portal pressure after ARC placement.

Postoperative data recorded included short-term postoperative (<1 month) deaths as well as 4–14 week postoperative trans-colonic nuclear scintigraphy results. Nuclear scintigraphy results were interpreted as “positive” for residual shunting if the calculated shunt fraction was ≥15% and “negative” if it was <15%.

**Follow-up**

Outcome information was obtained by telephone interview with the referring veterinarian and/or the owner. Specific inquiries made were: whether the dog was alive, dead, or euthanatized; if dead or euthanatized, when the event occurred and what circumstances surrounded the event; use of medical management for hepatic encephalopathy (antibiotics, lactulose, or a protein restricted diet) at time of death or euthanasia, or currently if still alive; presence of clinical signs related to hepatic encephalopathy (mental dullness, inappropriate mention, ataxia, head pressing, star gazing, and/or seizures) at time of death or euthanasia, or currently if still alive; and presence of ascites at time of death or euthanasia, or currently if still alive. For any death or euthanasia event, relevant details were recorded to facilitate discerning those events that could be CEHPSS-associated (hepatic encephalopathy, seizures, liver failure, ascites, or euthanatized or died <1 month postoperatively).

If sufficiently detailed and reliable information could not be obtained to allow definitive categorization, the death or euthanasia event was deemed to be because of “unknown cause” and only the date of the event was used for data analysis. Total lifespan of dogs that were determined to be dead or euthanatized was calculated based on age at the time of surgery and the date of death or euthanasia event. For dogs that were determined to be dead or euthanatized but the date of the event was unknown, no total lifespan was recorded and these dogs were considered lost to follow-up at the last known date of veterinary contact.

Based on data collected from the inquiries described above, categorical outcome grades were determined for each dog, as previously described.\textsuperscript{7} Briefly, an outcome grade of excellent was defined as a clinically normal dog with no medical management of hepatic encephalopathy, good was defined as a clinically normal dog that is receiving medical management of hepatic encephalopathy, and poor was defined as a dog with clinical signs attributable to CEHPSS or any dogs that died during the short-term postoperative period. Binary outcomes were assigned as follows: a successful outcome was a clinically normal dog not receiving medical management for CEHPSS and an unsuccessful outcome was a dog with or
without clinical signs attributable to CEHPSS that was receiving medical management of hepatic encephalopathy.

**Statistical Analyses**

Descriptive data were evaluated for normality using the D’Agostino-Pearson omnibus test with data that passed the test being reported as mean ± SD and data failing the test being reported as median and range. Correlation of age, preoperative WBC, preoperative albumin, and BA values with days since first surgery was performed by Pearson’s correlation. Mean days since first surgery were compared between dogs with and without neurologic signs by Student’s t-test. Student’s t-test was also used to compare age, preoperative WBC, serum albumin concentration, and BA values between intact and neutered dogs. Association of intact status and presence of neurologic signs was tested by a χ² test.

Median survival time after surgery was estimated with Kaplan–Meier analysis. During Kaplan–Meier analysis, censored dogs included those that were alive at last follow-up, lost to follow up, and those that died of non-CEHPSS related causes; any death deemed because of “unknown cause” was treated as CEHPSS-related in the Kaplan–Meier analysis.

Association of perioperative variables with survival was performed by log-rank tests for categorical variables and Cox regression for continuous variables. Association of perioperative variables with binary outcomes (successful or unsuccessful) and short-term postoperative death were assessed by logistic regression. Association of perioperative variables with categorical outcome grades (excellent, good, or poor) was assessed by Kruskal–Wallis and Mann–Whitney tests for categorical variables and Spearman correlation for continuous variables. If quasi-separation of variables occurred, Firth’s penalized maximum likelihood estimation method was used to reduce bias in logistic model parameter estimation.

All hypothesis tests were 2-sided and the significance level was P < .05. Each statistical result was reported with its corresponding odds ratio (OR), hazard ratio (HR), and/or 95% confidence interval (CI), as indicated by test performed. Data analyses were performed using commercially available statistical softwares (Graphpad Prism v5.03 for Windows, Graphpad Software, San Diego, CA [Descriptive data] and SAS v9.2, SAS Institute, Cary, NC [all other analyses]).

**RESULTS**

**Study Population and Signment**

Two hundred six dogs were included; 111 (53.9%) dogs had surgery at UCD, 55 (26.7%) at NCSU, and 40 (19.4%) at UGA. Median age at surgery was 12.0 months (range, 2–122 months). Sixty-nine (33.5%) dogs were >24 months old at surgery. Intact dogs were significantly younger (median age, 7 months; range, 2–29 months) compared with 24 months (range, 2–122 months; P < .0001) and significantly more likely to have preoperative neurologic signs (58% vs. 43%, respectively; P = .0359) than gonadectomized dogs. Sex distribution was 48 (23.3%) intact females, 67 (32.5%) spayed females, 43 (20.9%) intact males, and 48 (23.3%) castrated males. Breed distribution included 66 (32.0%) Yorkshire Terriers, 59 (28.6%) “other” breeds, 23 (11.1%) Miniature Schnauzers, 19 (9.2%) Maltese, 18 (8.7%) Shih Tzus, 13 (6.3%) Pugs, and 8 (3.9%) Miniature Poodles.

**Preoperative Data**

Median body weight at surgery was 3.6 kg (range, 0.9–39.0 kg). Clinical signs of hepatic encephalopathy (e.g. mental dullness, inappropriate mentation, ataxia, head pressing, staring, and/or seizures) were present in 101 (49.0%) dogs at presentation. Total WBC concentrations were available for 175 (85.0%) dogs with a median value of 14.3 × 10³ cells/µL (range, 5.3–52.4 × 10³ cells/µL; reference interval, 6–13 × 10³ cells/µL). Serum albumin concentrations were available for 188 (91.3%) dogs with a mean ± SD value of 2.5 ± 0.5 g/dL (reference interval, 2.9–4.2 g/dL). Pre-prandial BA were measured in 134 (65.0%) dogs with a median value of 108.4 µmol/L (range, 2.9–544.0 µmol/L; reference interval, 0–12 µmol/L). Postprandial BA were measured in 141 (68.4%) dogs with a median value of 228.9 µmol/L (range, 0.5–624.0 µmol/L; reference interval, 0–16 µmol/L).

**Intraoperative Data**

Shunt location was recorded for 199 (96.6%) dogs with 135/199 (67.8%) being portocaval and 64/199 (32.2%) being described as portoazygous. Temporary test occlusion portal pressure was recorded for 119 (57.8%) dogs with a median value of 14.0 mmHg (range, 3.0–50.0 mmHg). The magnitude of change from baseline portal pressure this represented was recorded in 117 of these 119 (98.3%) dogs with a median value of 7.0 mmHg (range, 0.0–36.5 mmHg). The final portal pressure after ARC placement was recorded in 82 (39.8%) dogs with a median value of 7.0 mmHg (range, 1.0–20.0 mmHg).

**Postoperative Outcome Data**

Fifteen of 206 (7.3%) dogs died in the short-term (<1 month) postoperative period. Of 191 dogs that survived >1 month, 116 (60.7%) had transcolonic nuclear scintigraphy between 4 and 14 weeks postoperatively. Of these, 28 (24.1%) had positive nuclear scintigraphy results indicating continued shunting and 88 (75.9%) were test negative for persistent shunting.

Follow-up data was obtained for 112 (58.6%) of 191 dogs surviving >1 month. Median time from surgery to follow up was 54 months (range, 1–175 months). Median age at follow-up was 103 months (range, 4–229 months). Outcome grade assigned to dogs at follow-up included 84/112 (75.0%) dogs as excellent, 19 (17.0%) as good, and 9 (8.0%) as poor outcomes. When divided by successful versus unsuccessful binary outcomes, 84/112 (75.0%) and 28/112 (25.0%) dogs were in each category, respectively.
Forty-eight (43%) of 112 dogs for which follow-up information was available were documented to have died or been euthanized by the time of last follow-up. Nineteen (17%) of these death or euthanasia events were attributed to CEHPSS or related causes (5 postoperative hemorrhage, 5 multiple acquired shunts ± ascites, 4 seizure, 2 unspecified postop deaths, and 1 each of: mesenteric thrombus, hepatic encephalopathy, and hepatic failure). Median age at the time of death for these 19 dogs was 36 months. Eighteen (16%) of these death or euthanasia events were determined to be unrelated to CEHPSS (4 chronic renal failure, 2 congestive heart failure, 2 respiratory distress, and 1 each of: hit by car, unspecified trauma, gall bladder rupture, snakebite, diabetes mellitus, pancreatic neoplasia, spinal neoplasia, mammary neoplasia, unspecified neoplasia, and an owner-requested euthanasia). Median age at the time of death for these 18 dogs was 141 months. The remaining 11 (22.9%) death or euthanasia events could not be confidently assigned to either category. Results of postoperative nuclear scintigraphy for these 48 dogs are in Table 1. Median total lifespan for these 48 dogs was 115 months (range, 3–197 months). When survival is estimated in all 206 study dogs using a Kaplan–Meier curve, the median survival time is 153 months (Fig. 1).

**Prognostic Factors**

All variables significantly associated with postoperative outcome are listed below. Survival beyond the short-term (1 month) postoperative period was significantly associated with an intact sexual status (OR = 5.6; 95% CI = 1.2, 25.3; \(P = 0.0266\)) and a decrease in preoperative total WBC (OR = 0.919; 95% CI = 0.871, 0.969; \(P = 0.0017\)). Intact dogs also had a longer overall median survival time compared to gonadectomized dogs (intact = 187 [95% CI = 147, not calculable] vs. gonadectomized = 137 months [95% CI = 130, 157]; \(P = 0.0129\)). The probability of overall survival was significantly decreased in dogs with higher pre-prandial BA (HR = 0.997; \(P = 0.422\)). The probability of overall survival was significantly increased in dogs with higher preoperative total WBC (HR = 1.041; \(P = 0.0268\)) and higher intraoperative temporary test occlusion portal pressures (HR = 1.033; \(P = 0.0482\)).

Dogs experiencing a successful binary outcome were more likely to have had surgery later in the study period (OR = 1.002; 95% CI = 1.000, 1.003; \(P = 0.0087\)) and were more likely to have had negative postoperative nuclear scintigraphy results (OR = 10.7; 95% CI = 1.7, 66.0; \(P = 0.0246\); Table 2). Having surgery later in the study period was also positively correlated to outcome grade (\(r = 0.37\); \(P = 0.056\); Table 3). Although not associated with any measures of survival or outcome, age (\(r = 0.15\), \(P = 0.0305\)) and preoperative serum albumin concentration (\(r = 0.18\), \(P = 0.0151\)) were significantly correlated with days since the first surgery.

![Kaplan–Meier survival curve for 206 dogs treated for congenital extrahepatic portosystemic shunt (CEHPSS) by surgical ameroid ring constrictor placement between 1995 and 2001. Vertical has marks represent dogs censored from analysis. Dashed lines above and below the primary curve represent the 95% confidence interval. Dogs were censored because they were lost to follow up, still alive at the time of follow-up, or died because of causes unrelated to CEHPSS.](image)

**Table 1** Four to 14 Week Postoperative Trans-Colonic Nuclear Scintigraphy Results in Dogs That Were Documented to Have Died or Been Euthanatized by the Time of Last Follow-Up

<table>
<thead>
<tr>
<th>Cause of Death or Euthanasia</th>
<th>Nuclear Scintigraphy*</th>
<th>Nuclear Scintigraphy*</th>
<th>Nuclear Scintigraphy Not Performed</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEHPSS-related ((n = 19))</td>
<td>0 (0%)</td>
<td>4 (21%)</td>
<td>15 (79%)</td>
</tr>
<tr>
<td>Not CEHPSS-related ((n = 18))</td>
<td>11 (61%)</td>
<td>3 (17%)</td>
<td>4 (22%)</td>
</tr>
<tr>
<td>Unknown ((n = 11))</td>
<td>8 (73%)</td>
<td>1 (9%)</td>
<td>2 (18%)</td>
</tr>
</tbody>
</table>

CEHPSS, congenital extrahepatic portosystemic shunt.

* Nuclear scintigraphy results were interpreted as "positive" for residual shunting if the calculated shunt fraction was \(\geq 15\%\) and "negative" if \(< 15\%\).

**Table 2** Total Number of Dogs With Positive and Negative Postoperative Nuclear Scintigraphy Results and Associated Outcome

<table>
<thead>
<tr>
<th>Nuclear Scintigraphy Result</th>
<th>Postoperative Total Number of Dogs</th>
<th>Successful Outcome</th>
<th>Unsuccessful Outcome</th>
<th>Outcome Not Be Determined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive result ((\geq 15%))</td>
<td>28</td>
<td>7</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Negative result (&lt; 15%))</td>
<td>88</td>
<td>53</td>
<td>11</td>
<td>24</td>
</tr>
</tbody>
</table>

A successful outcome was a clinically normal dog not receiving medical management for CEHPSS and an unsuccessful outcome was a dog with or without clinical signs attributable to CEHPSS that was receiving medical management of hepatic encephalopathy. Numbers in columns represent numbers of dogs. Having a negative nuclear scintigraphy increased a dog’s odds of a successful outcome by nearly 11-fold versus a positive result (OR = 10.7; 95% CI = 1.7, 66.0; \(P = 0.0246\)).
Table 3  Total Number of Dogs With Follow-Up Information Available for Each Year Which Surgery Was Performed and Associated Categorical Outcome Grades

<table>
<thead>
<tr>
<th>Year</th>
<th>Dogs Which Underwent Surgery in This Year</th>
<th>Excellent Outcome</th>
<th>Good Outcome</th>
<th>Poor Outcome</th>
<th>Follow-Up Not Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>1996</td>
<td>14</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>1997</td>
<td>39</td>
<td>8</td>
<td>3</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>1998</td>
<td>38</td>
<td>11</td>
<td>6</td>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>1999</td>
<td>44</td>
<td>22</td>
<td>2</td>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td>2000</td>
<td>45</td>
<td>23</td>
<td>6</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>2001</td>
<td>21</td>
<td>17</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

An outcome grade of excellent was defined as a clinically normal dog with no medical management of hepatic encephalopathy, good was defined as a clinically normal dog that is receiving medical management of hepatic encephalopathy, and poor was defined as a dog with clinical signs attributable to CEHPSS or any dogs that died during the short-term postoperative period. The numbers in columns represent numbers of dogs.

DISCUSSION

This study was designed to obtain long-term outcome data for 206 dogs that had relatively uniform surgical treatment for a single CEHPSS by ARC placement. In addition to descriptive information, we evaluated perioperative variables suspected of having a significant association with long-term survival. Our study was designed to complement and expand upon a previous publication that reported 3-year postoperative outcomes for a subset of our study population.

Perhaps the most notable finding of our study is the long-term survival data. Estimated median survival time for the overall study population was over 12.5 years (153 months). From evaluating the Kaplan–Meier survival curve with associated 95% CI, it is apparent that dogs surviving the short-term postoperative period lived out a relatively normal lifespan. The slope of the survival curve towards the far right end must be interpreted with caution as very few subjects at risk remained within the analysis at that point, as is reflected by the wide 95% CI by that point in the graph. Finally, our Kaplan–Meier analysis was performed with the most stringent criteria, wherein all dogs with deaths because of undetermined causes were assumed to be CEHPSS-related. In fact, many of these deaths may represent end-of-life events of an aging population of dogs and be unrelated to their historical CEHPSS diagnosis.

These data provide a strong argument for the generally successful treatment outcome of CEHPSS by surgical ARC placement as most dogs will apparently experience a relatively normal lifespan, often dying of non-CEHPSS causes. Two variables found to be significantly associated with longer overall survival times include dogs that were intact at the time of surgery and those with lower preoperative prandial BA values. As age was significantly correlated to intact sexual status, these findings may reflect the regenerative potential of a young dog’s liver and potential ability to reverse and/or prevent chronic CEHPSS-associated hepatic pathology and dysfunction.

Categorical outcome grades (excellent, good, poor) and binary outcome classifications (successful, unsuccessful) were assigned using simple, uniform criteria to study dogs at time of follow-up. As described previously, categorical scores were assigned based on whether each dog had clinical signs, required medical management for hepatic encephalopathy, or died or been euthanatized because of a CEHPSS-related event. These variables were chosen for consideration in order to create outcome grades which would be reflective of quality of life and the degree of care each dog required. Other authors have used BA as an assessment of outcome.³,¹¹ Measurement of BA was not used in our outcome evaluation. In future prospective studies, long-term measurement of BA may provide more information about chronic liver function. However, while likely, it is unknown if BA or change in BA is highly correlated with clinical outcome. Additionally, BA may be elevated for reasons unrelated to CEHPSS, especially in the dogs that had surgery a decade earlier.

Several perioperative variables were found to be significantly associated with long-term postoperative outcomes. A successful outcome (no clinical signs of hepatic encephalopathy with no medical management for CEHPSS) was more likely to be experienced by dogs with negative postoperative nuclear scintigraphy results as well as those dogs that had surgery later in the study period. Undergoing surgery later in the study period also was also significantly positively correlated with higher categorical outcome grades. This association was highly significant but small in magnitude. Although it is possible this slow but steady improvement in outcome over the years of the study is because of increasing familiarity with ARC surgical technique and/or improved postoperative management of critically ill surgical patients, we must also point out that the date of surgery was not significantly associated with short-term postoperative survival. It remains possible that the participating surgeons’ ability to correctly identify the morphology of more complex shunts and place the ARC in the most clinically efficacious position improved over the study period, resulting in a better long-term outcome. Dog age and preoperative serum albumin concentration was directly correlated to the number of days since the first surgery. This may be because our ability to identify older dogs with no or mild clinical signs improved over time, and older dogs typically have higher serum albumin concentrations than younger dogs.¹⁴ Additionally, as surgeons gained experience with ARC placement and evidence emerged that surgical therapy improved survival, our profession may have become more willing to operate older dogs.

A large proportion of the dogs in our study (>60%) of those surviving the short-term postoperative period had 4–14 week postoperative recheck trans-rectal nuclear scintigraphy. Dogs with a negative postoperative nuclear scintigraphy scan were >10 times more likely to experience a successful long-term outcome. This was the strongest predictor of long-term outcome in our study and is consistent with the report by Mehl et al.⁷ Twenty-four percent of dogs had evidence of continued shunting in our study. Reasons for continued postoperative
shunting could include development of multiple acquired shunts (secondary to portal hypertension), failure of the ARC to completely occlude the shunt vessel, or inappropriate ARC placement because of unrecognized shunt morphology (e.g. double loop shunt morphology).\textsuperscript{1,3,15} As reported previously, the clinical outcome for these dogs was highly variable, and likely depends on the degree of residual shunting, portal vascular supply, and hepatic development after surgery.\textsuperscript{7}

The short-term postoperative death rate in the current study was 7.3% (15/206 dogs), which is consistent with previous reports for surgical treatment of CEHPSS. However, as noted previously,\textsuperscript{7} direct comparison across studies is complicated by variations in definition of short-term postoperative death: some studies consider this to be limited to <1 week postoperatively, others expand the period until suture removal, and others use <1 month.\textsuperscript{3,7,16–18} Perioperative variables found to be significantly associated with short-term postoperative survival included a lower total WBC and an intact sexual status. Consistent with the study by Mehl et al., for every 1000 cells/µL increase in preoperative total WBC count, the probability of short-term death increased by ~9%. Dogs that were sexually intact (vs. being castrated or spayed) were >5 times more likely to survive the short-term postoperative period. Although neither age nor presence of neurologic signs at time of presentation were found to be significantly associated with outcome measures, dogs that were sexually intact were significantly younger (median of 7 vs. 24 months) and more likely to display neurologic signs (58% vs. 43%) at the time of surgery than gonadectomized dogs. These results suggest that intact sexual status, age, and presence of neurologic signs are all related factors. Intuitively this conforms to the idea that dogs with neurologic signs are more likely to undergo surgical treatment for CEHPSS at a younger age and therefore still be sexually intact. Additionally, these dogs may have greater capacity for hepatic regeneration and therefore have a better long-term survival. Therefore, it is possible that being intact may not be a true predictor of postoperative survival, but appears to be because of its association with age.

The signalment, historical, physical examination, preoperative diagnostic, intraoperative findings, and short-term postoperative mortality of our study population are generally consistent with historical reports on CEHPSS, with a few notable variations.\textsuperscript{1–5,7,9,16,17,19–25} Although the median age at the time of surgery was 12 months, 33.5% of the dogs were >2 years old at surgery. Dogs with CEHPSS that are diagnosed and treated at an adult age may be more commonly affected with portoazygous shunts\textsuperscript{22,24,26,27} and the prevalence of portoazygous shunts was somewhat higher in our population (32.2%) than is typically reported for dogs with CEHPSS. A recent study by Nelson and Nelson,\textsuperscript{15} using CT angiography, details various CEHPSS morphologies in dogs, with far greater anatomic detail than was recorded in the medical records of our study. Nelson and Nelson described a common variant of portocaval shunt anatomy in which the shunt travels into the crus of the diaphragm and inserts into the phrenic vein (and from there into the caudal vena cava). They suggested that some extrahepatic shunts historically described as portoazygous because of their proximity to the diaphragmatic crura could have appeared similar in morphology to this anatomic variant.\textsuperscript{15} This is a potential explanation for the high proportion of “portoazygous” shunts documented in the present study.

Clinical signs of hepatic encephalopathy (e.g. mental dullness, inappropriate mentation, ataxia, head pressing, star gazing, and/or seizures) were noted in 49% of our population at time of presentation, which is at the lower end of previously published reports ranging from 45% to 79%.\textsuperscript{2,3,10,22–24} Taken together, this information suggests the dogs in our study can be considered generally representative of dogs with CEHPSS treated with ARC placement, and our findings should be applicable to other dogs treated in a similar fashion.

The significant association between higher intraoperative temporary test occlusion portal pressure and longer survival contradicts the previous report by Mehl et al.\textsuperscript{7} The reason for this is unclear, as dogs with a more robust portal vasculature should have lower occlusion pressures and should have more normal anatomy, which one would believe would lead to a better chance of a longer survival. The reason for this discrepancy is unknown, but the method of obtaining pressures was not uniform and technique may vary between institutions in regard to specific anesthetics and measurement techniques.

Additionally, our finding that a higher preoperative WBC was associated with lower chances of surviving the short-term postoperative period but was also associated with improved overall survival are somewhat contradictory and likely involves the interplay of a variety of complex risk factors, not all of which were evaluated in our study. Another possible contribution to both of these differences is the expansion of our study population with additional dogs from UGA, which influenced the perioperative characteristics and postoperative death rate. Furthermore, it is important to bear in mind that our study was designed to evaluate outcome at a notably longer follow-up time, by which point, the relationship between certain perioperative variables and outcome may have changed as compared to historic reports.

Limitations of our study center on its retrospective nature. Time of surgery was upwards of 17 years before follow-up for some of dogs in our study. Every effort was made to contact referring veterinarians and owners, but because of the extended time since surgery many individuals were untraceable, medical records discarded, or clinics closed. Finally, a large number of cases were lost-to-follow-up with only 112 of the original 206 dogs having long-term data available for evaluation. This case attrition could mask potentially important information or findings in our current study.

We concluded that dogs with CEHPSS undergoing surgical treatment with ARC placement generally have a good prognosis and prolonged postoperative survival. Contrary to our hypothesis, the perioperative variables significantly associated with short-term postoperative death and long-term outcome in the prior publication\textsuperscript{7} changed with the extension of the follow-up period and expansion of sample size. Specific factors were prognostic for surviving the short-term postoperative period (intact sexual status and lower total WBC count), experiencing better long-term outcomes (surgery at a later date in the study period and negative recheck nuclear scintigraphy results), and experiencing longer overall survival (intact sexual...
status, higher preoperative WBC value, lower preoperative BA value, and a higher intraoperative temporary test occlusion portal pressure value).

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**DISCLOSURE**

The authors report no financial or other conflicts related to this report.

**REFERENCES**