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**Full Title**

# Variations in surgical technique for adrenalectomy with caudal vena cava venotomy in 19 dogs

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**Abstract**

***Objective*****:** To describe variations in surgical technique and caval occlusions times in dogs undergoing adrenalectomy with caval venotomy.

***Study Design*****:** Retrospective case series.

***Animals*****:** Dogs undergoing adrenalectomy with caval venotomy from 2010 to 2018.

***Methods*****:** Medical records of dogs undergoing adrenalectomy with caval venotomy were reviewed for signalment, perioperative management, surgical details, perioperative complications, mortality, and histopathology. Computed tomography images were reviewed to describe tumor morphology and signs of thrombus extension.

***Results*****:** There were 19 dogs with adrenal tumor thrombi extending into the pre-hepatic (14 dogs, 74%), hepatic (3 dogs, 16%) and post-hepatic (2 dogs, 11%) caudal vena cava. The left adrenal gland (58%) was more commonly affected than the right (42%). Median caval occlusion was 6.5 minutes, ranging from 2 to 25 minutes. Between two and six vascular tourniquets were used. Venotomy closure was performed under full caval occlusion in 58% and using a partial occlusion clamp in 42%. Left ureteronephrectomy was performed in 26%. Peri-operative mortality rate was 21%.

***Conclusions*****:** Ureteronephrectomy is much more likely to be required on the left side. Venotomy closure under full occlusion was performed more commonly for right adrenal tumors. Number of vascular tourniquets used reflected the location of phrenicoabdominal vein insertion on the cava and length of the caval tumor thrombus. Longer caval occlusion than previously reported may be tolerated in some clinical cases.

***Clinical Significance*:** Review of surgical technique for adrenalectomy with caval venotomy, including differences between right and left tumors, should provide useful information for surgeons planning this procedure.

**Introduction**

Extension of a tumor thrombus into the caudal vena cava (CVC) is reported in canine pheochromocytomas and adrenocortical adenocarcinomas. This finding adds complexity to the surgical procedure, and extends the surgical time because of the need for venotomy to remove the intracaval tumor thrombus (Figure 1).[1-2] There is conflicting data in the literature regarding CVC thrombus extension as a possible risk factor for perioperative mortality during adrenalectomy, probably reflecting variations in the extent of CVC thrombus between studies.[2-7] Also, there are few descriptions of the nature and extent of CVC invasion or the surgical techniques required to treat this, such as use of vascular tourniquets, partial versus complete occlusion, and methods of venotomy closure. There are no clinical studies that report the caval occlusion times required or tolerated during venotomy by any technique for dogs undergoing adrenalectomy.

One report of 10 dogs with adrenal tumors described the extent of CVC thrombus; eight dogs with pre-hepatic and one dog with an intra-hepatic CVC thrombus were treated by temporary CVC occlusion using two vascular tourniquets followed by CVC venotomy closure over a partial occlusion clamp, and one dog with an extensive intra-hepatic CVC thrombus, which was deemed non-resectable, died during surgery.[2] In a larger study of 27 dogs with adrenal tumors invading the CVC, some dogs had a venotomy entirely performed over a partial occlusion clamp and others had venotomy closure over a partial occlusion clamp after the thrombus had been removed under full CVC occlusion.[4] The details of how many dogs were treated by each method, the number and location of vascular tourniquets, the duration of CVC occlusion and extent of the CVC thrombus (pre, intra or post-hepatic CVC) were not reported.[4] In another report, three dogs had a CVC venotomy closed over a partial occlusion clamp.[1] The extent of tumor thrombi in these three dogs was not described, but two dogs also received a median sternotomy to help “milk” the tumor thrombus out through an abdominal CVC incision, which was performed separately to the adrenalectomy, i.e. the thrombus was not removed en bloc with the primary adrenal tumour.[1] In two reports, CVC venotomies for adrenal tumor removal were performed under full CVC occlusion, although neither describe the extent of the CVC invasions.[5,6] One study described seven dogs with adrenal tumor thrombus extension confined to the pre-hepatic CVC and seven dogs with CVC thrombus extending beyond the hepatic hilus, but no details of the surgical techniques used to excise the thrombi were included.[3]

The degree of thrombus extension (pre-hepatic, hepatic, post-hepatic), affected adrenal (left or right), location of the insertion of the phrenicoabdominal vein on the CVC (Figure 2), width of the phrenicoabdominal vein (distended by tumor) and type of tumor invasion into the CVC (direct phrenicoabdominal vein extension, direct CVC wall invasion or extension via the renal vein) affects the complexity that extraction of the tumor via CVC venotomy represents and thus the surgical techniques employed, including the number and location of tourniquets for CVC occlusion (Figures 3 and 4), length of CVC occlusion time and choice of venotomy technique. The aim of the present study was to describe variations in surgical technique, with a rationale for doing so where appropriate, and the duration of temporary CVC occlusion in a series of dogs undergoing adrenalectomy with CVC venotomy for treatment of adrenal neoplasia.

## Materials and Methods

Medical records were searched for dogs that had adrenalectomy with CVC venotomy for treatment of primary adrenal gland neoplasia between October 2010 and May 2018. Dogs were included if CVC venotomy was performed for adrenal tumor thrombectomy and pre-operative computed tomography (CT) images were available for review. Dogs with adrenal tumors and phrenicoabdominal vein invasion treated by adrenalectomy with phrenicoabdominal vein ligation only were excluded. Details of signalment, presenting clinical signs, pre-operative endocrine testing, pre-operative medication, anesthetic management and surgical technique (including number and location of tourniquets, length of CVC occlusion time and venotomy closure method), hospitalization time, perioperative complications, mortality, and histopathological analysis were recorded. Pre-operative CT examinations were acquired using a multi-slice scanner (MX8000 IDT, Phillips, Best, The Netherlands) and images reviewed using a proprietary DICOM viewer (Image Viewer Version 4.1, Visbion Ltd, Chertsey, UK). CT settings were helical acquisition, slice thickness up to 3mm, medium frequency (‘soft tissue’) reconstruction algorithm, with post-contrast CT images acquired 60 seconds after the start of intravenous injection of 2ml/kg of iohexol 300mg/ml (Omnipaque 300, GE Healthcare, Oslo, Norway). CT images were reviewed by a board-certified radiologist to determine size, shape and attenuation (Hounsfield units, HU) of the primary tumor, extent of vascular invasion, signs of invasion of other structures, and signs of metastasis. Length of extension of tumor thrombus into the CVC was categorized as pre-hepatic, hepatic or post-hepatic CVC.

*Pre-operative Management*

Initial evaluation included complete blood count, biochemistry and urine analysis. Endocrine testing was performed using the adrenocorticotropic hormone (ACTH) stimulation test, low-dose dexamethasone suppression test, urine cortisol to creatinine ratio, and measurement of serum metanephrine and normetanephrine levels. Abdominal ultrasound was used in some cases for identification of the adrenal tumor, with thoracic and abdominal CT performed in all dogs for staging and surgical planning. Based on the results of endocrine testing dogs were treated medically prior to surgery with trilostane (if hyperadrenocorticism was confirmed) or phenoxybenzamine (if a pheochromocytoma was confirmed or suspected).

*Anesthetic Management*

The anesthetic protocol was tailored for each dog at the discretion of a board-certified anesthesiologist. Cefuroxime or amoxicillin-clavulanate (20mg/kg intravenously [IV]) was administered at least 20 minutes prior to the first incision and every two hours during general anesthesia. Dogs with a cortisol secreting tumor were administered a constant rate intravenous infusion of hydrocortisone at 0.5 mg/kg/h from one hour pre-operatively and throughout surgery. Severe intra-operative hypertension and/or arrhythmias were treated with nitroprusside or lidocaine if necessary. Management of hypotension was by rapid expansion of volume by crystalloids, colloids and/or blood products, as well as administration of dopamine, dobutamine or epinephrine when required.

*Surgery*

A ventral midline celiotomy and full abdominal exploration was performed in all dogs, with extension to a median sternotomy in one dog. The adrenal mass was isolated from the surrounding tissues using a combination of blunt and sharp dissection with Mixter forceps, Metzenbaum scissors, hemoclips and diathermy until the only remaining attachment was the insertion of the phrenicoabdominal vein on the CVC (Figure 3). Left-sided tumors were passed underneath the mesentery so as to be the same side of the abdomen as the CVC to optimize exposure for the venotomy (Figure 4). Rummel tourniquets were placed around the abdominal CVC cranial and caudal to the tumor thrombus (Figure 3) and in some cases around one or both renal veins (Figure 4), the thoracic CVC and the portal vein and hepatic artery together at the level of the epiploic foramen (Pringle maneuver) depending on the location of insertion of the phrenicoabdominal vein on the CVC and the extent of the CVC thrombus. The plan for the CVC occlusion, venotomy and vein closure was summarized by the lead surgeon and confirmed with the surgical and anesthesia teams before starting the theatre clock for timing of the CVC occlusion. Renal vein tourniquets were tightened before CVC tourniquets, and caudal CVC were tightened before cranial CVC tourniquets. CVC venotomy was performed using a combination of a number 11 scalpel and Potts scissors around the insertion of the phrenicoabdominal vein and extended along the CVC as required to allow removal of the tumor thrombus. Some venotomy closures were performed under partial occlusion with a tangential clamp placed parallel to the incision and the Rummel tourniquets released, taking care that the edges of the vein within the clamp were matched correctly to each other and sufficiently wide to accept good bites of suture.  Alternatively, some venotomies were sutured under complete CVC occlusion, in which case the starting knot of the continuous suture pattern was pre-placed and tied prior to starting the CVC occlusion and performing the venotomy. Venotomies were closed under complete CVC occlusion if the venotomy was too large for the tangential clamp to be placed around it or if the location of the phrenicoabdominal vein insertion and subsequent venotomy precluded space for a clamp. A single or double simple continuous suture line with 4-0, 5-0 or 6-0 polypropylene was used for venotomy closure, with an absorbable hemostatic agent (Surgicel, Ethicon, Somerville, NJ) applied in some dogs at the discretion of the surgeon. Concurrent ureteronephrectomy was performed in some dogs during initial dissection of the adrenal tumor due to tumor invasion of the kidney (Figure 5) and/or renal vein or, at a later stage, due to irreparable damage to the renal vein during CVC venotomy.

*Post-operative Care*

All dogs were monitored in the intensive care unit post-operatively until fully recovered from anesthesia and considered stable enough to be transferred to the surgical ward until discharge from the hospital. Post-operative analgesia was provided at the discretion of the anesthesiologist, based on pain scoring.[8] Dogs with a cortisol secreting tumor had their constant rate intravenous infusion of hydrocortisone reduced to 0.25 mg/kg/h at the end of surgery and continued for a further 24 hours. Oral prednisolone treatment was then initiated, with dosing gradually tapered over the following months based on progress at re-examination and subsequent ACTH stimulation tests. Dogs on pre-operative phenoxybenzamine did not continue with this medication post-operatively.

## Results

*Signalment and Presentation*

Nineteen dogs met the inclusion criteria for the study; 10 were males (9 neutered), and 9 were females (8 neutered). Median age was 11.3 years (range 6.7-14 years) and median bodyweight was 12.2 kg (range 5.7-41.3 kg). Thirteen breeds were represented and there were six crossbreeds. There were ten males (nine neutered) and nine females (eight neutered) dogs. Presenting clinical signs, complete blood count, biochemistry testing and urine analysis were largely non-specific and consistent with other reports of dogs presenting with functional adrenal tumors. Endocrine testing confirmed hyperadrenocorticism in three dogs (16%), was consistent with pheochromocytoma in 14 dogs (74%), with a progesterone-secreting tumor in one dog (5%) and with a non-functional tumor in one dog (5%). Dogs with hyperadrenocorticism were treated with trilostane pre-operatively, with a median dose of 2 mg/kg (range 1.4-2.4 mg/kg) once daily. Twelve of 14 dogs with suspected pheochromocytoma were treated with phenoxybenzamine, with a median dose of 0.5 mg/kg (range 0.27-2.5 mg/kg) twice daily for between 4 and 21 days pre-operatively.

*Diagnostic Imaging*

Thoracic and abdominal CT was performed in all dogs, as per the inclusion criteria. The left adrenal gland (11 dogs, 58%) was more frequently affected than the right (eight dogs, 42%). Median transverse diameter of adrenal neoplasms on CT was 22 mm (range 12-63 mm). The contralateral adrenal gland was considered normal size in 68%, subjectively enlarged in 16% and subjectively small (compatible with atrophy) in 16% cases. On the basis of CT, neoplasms were rounded (14/19) or lobular (5/19), all except one had a well-defined outline, 12 of 19 dogs had a regular border, 4 of 19 had an irregular border, and 3 of 19 had signs of infiltration into the adjacent retroperitoneal fat. According to pre-contrast CT images, adrenal tumors appeared homogeneous (12/19, heterogeneous (1/19) or calcified (7/19). The median pre-contrast attenuation was 48 HU (range 39-67 HU) and median post-contrast attenuation was 102 HU (range 44-220 HU), with a median increase of 47 HU (range 10-162 HU) after contrast administration. Degree of contrast enhancement was classified as slight (<60 HU) in 13 of 19, moderate (60-110 HU) in 4 of 19, and marked (>110 HU) in 2 of 19 dogs. After contrast administration, adrenal tumors appeared equally homogeneous (9/19) and heterogeneous (10/19).

Extension of tumor into the CVC and phrenicoabdominal vein was visible on the CT in all dogs, with left renal vein invasion identified in 16% (three dogs), all with pheochromocytomas. On the basis of the extent of the intraluminal filling defect in post-contrast images, the thrombus extended to the pre-hepatic (14 dogs, 74%), hepatic (3 dogs, 16%) or post-hepatic (2 dogs, 11%) CVC, with a median length 15 mm (range 3-120 mm) cranial to the adrenal mass. In one dog the thrombus completely obstructed the CVC. There was evidence of tumor invasion into the adjacent retroperitoneum in one dog, and invasion into the diaphragm and epaxial muscles in one dog.

*Surgical Details*

Surgery was performed by four board-certified surgeons, with one surgeon performing nine procedures, one performing six procedures, and the remaining two surgeons each performed two procedures. Median surgical time was 190 minutes (range 130-420 minutes) and median anesthetic time was 265 mins (range 190-490 mins). Regional analgesia was provided with epidural morphine in 14 dogs and a transverse abdominis plane block using ropivacaine in two dogs. Methadone (0.1-0.3 mg/kg IV) was administered to all dogs perioperatively and 14 dogs also received a fentanyl or remifentanil constant rate infusion intra-operatively. A single dose of heparin sodium solution for injection (50 I.U./kg [IV]) was administered to all dogs 5-10 minutes before starting the CVC venotomy.

Two Rummel tourniquets were used on the pre-hepatic CVC cranial and caudal to the thrombus (Figure 3) in 11 of 19 dogs (58%), four left sided and seven right sided tumors. Three Rummel tourniquets with an additional tourniquet on the left renal vein were used in one dog (5%) with a left adrenal tumor. Four Rummel tourniquets around the pre-hepatic CVC and both renal veins (Figure 4) were used in six dogs, (32%), all with left adrenal tumors. Six tourniquets were placed in one dog with a right adrenal tumor, with the additional Rummel tourniquets placed on the post-hepatic thoracic CVC and portal vein and hepatic artery together at the level of the epiploic foramen (Pringle maneuver). Overall median CVC occlusion time (n = 15) was 6.5 minutes (range 2 to 25 minutes). Median CVC occlusion time for venotomies sutured over a partial occlusion clamp (n = 5) was 3.83 minutes (range 2 to 5.5 minutes). Median CVC occlusion time for venotomies sutured under full occlusion was 7.88 minutes (range 6 to 25 minutes). Four dogs had extended CVC occlusion times of 9.85, 10, 17 and 25 minutes. The extended occlusion time of 9.85 minutes in one dog result from blockage of the suction machine and subsequent poor visibility during the venotomy. The occlusion times of 10, 17, and 25 minutes in three other dogs resulted from the extensive nature or length of the tumor thrombus requiring additional time to remove the tumor thrombus and perform the venotomy.

CVC venotomy closure was performed under complete occlusion in 11 dogs (58%), five left sided and six right sided tumors. CVC venotomy closure was performed under partial occlusion with a tangential clamp in 8 of 19 dogs (42%), six left sided and two right sided tumors. Closure was performed with 4-0 (1 dog; 5%), 5-0 (14 dogs; 74%), or 6-0 (4 dogs; 21%) polypropylene in a single (13 dogs; 68%) or double (6 dogs; 32%) simple continuous pattern. An absorbable hemostatic agent (Surgicel, Ethicon) was applied over the suture line in 12 dogs (63%).

Concurrent left ureteronephrectomy was performed in five dogs (26%) due to extension of the tumor thrombus into the left renal vein (one dog), tumor growth incorporating the left renal vein and kidney (two dogs) (Figure 5), and intra-operative damage to the left renal vein (two dogs). One dog with a right sided tumor required resection of a portion of the diaphragm to facilitate dissection of a large primary adrenal mass.

Histopathology was performed in 17 dogs, which confirmed pheochromocytomas (12 dogs; 71%) and adrenocortical adenocarcinomas (5 dogs; 29%). Vascular invasion was evident on histopathology in all tumors, with one dog having direct invasion through the CVC wall as well as via extension from the phrenicoabdominal vein.

*Perioperative Complications and Mortality*

Intra-operative complications were observed in 14 of 19 dogs (74%), including hypotension (n=12), hypertension (n=2), arrhythmias (n=3) hemorrhage (n=6), break in asepsis (n=1), and temporary jejunal ischemia due to occlusion of the cranial mesenteric artery during dissection of large left sided tumors that enveloped this artery (n =2) (Figure 6). Packed red blood cell transfusions were performed in five dogs after intra-operative hemorrhage, and two dogs received fresh frozen plasma. One dog died intra-operatively at the end of surgery after excision of the tumor and thrombus; the adrenal tumor was large and highly adherent, requiring prolonged dissection. There were multiple periods of hypotension and ventricular arrhythmias, which progressed to ventricular fibrillation and cardiopulmonary arrest. Resuscitation was attempted but was unsuccessful.

Post-operative complications occurred in 13 of 18 dogs (68%) including refractory hypotension (n=2), acute kidney injury (n=2), and one each of: pulmonary thromboembolism, hemoperitoneum, aspiration pneumonia, hypovolemia, self-resolving peripheral edema, persistent hypertension, a single episode of abdominal pain, and anorexia with hypoglycemia. Refractory hypotension developed in one dog immediately post-operatively on recovery from anesthesia and in another a few hours post-operatively. Both cases progressed to cardiac arrest and resuscitation was unsuccessful. Pulmonary thromboembolism was confirmed on post-mortem examination in one dog following respiratory arrest four days post-operatively. Repeat exploratory laparotomy was performed in the dog with hemoperitoneum, in which a retroperitoneal hematoma was found near the site of ureteronephrectomy, but no specific source of hemorrhage could be identified (the renal vessel pedicles and CVC venotomy sites were not bleeding). Autotransfusion was performed and the dog recovered with no further complications.

Median time to discharge was four days (range 3-11 days), and median time in the intensive care unit was two days (range 1-5 days). The 4 dogs with prolonged CVC occlusion times all survived to discharge. Overall perioperative mortality rate was 21% (four dogs). These dogs all had pheochromocytomas, with a median tumor size 28 mm (range 20-63 mm). The CVC thrombi were all pre-hepatic in these four dogs, extending 3-13 mm cranial to the adrenal mass. No dogs were euthanized intra-operatively due to the technical difficulties or the tumor being considered inoperable.

## Discussion

This report describes variations in surgical technique in dogs undergoing adrenalectomy with CVC venotomy for treatment of adrenal neoplasia, including the duration of temporary CVC occlusion tolerated. CVC occlusion for up to eight minutes has been reported to be safe in healthy experimental dogs,[9] but there is no information regarding CVC occlusion times in dogs with adrenal tumors. Most dogs in this study had a CVC occlusion time less than eight minutes, but four dogs had longer occlusion times of 9.85, 10, 17 and 25 minutes. These dogs all survived to discharge, suggesting that longer occlusion may be tolerated in selected patients, without adverse effects, presumably because in many cases gradual occlusion of the CVC to a significant extent by the tumor prior to surgery affords a degree of tolerance to full temporary occlusion during surgery. Further investigation is needed to determine safe or optimal CVC occlusion times in clinical patients and to improve our understanding of the factors involved.

Left (11/19) adrenal tumors occurred more frequently than right (42%) in this study, similar to one other report,[5] but not others.[2,3,6,10] A difference for surgeons to note when operating on left sided adrenal tumors, which is likely performed by others but has not been reported before, is the need to move the dissected out left adrenal tumor over to the right side of the abdomen prior to CVC venotomy to optimize exposure for this part of the procedure (Figure 4). The use of more than two Rummel tourniquets for vascular occlusion in dogs undergoing CVC venotomy for removal of adrenal tumors has also not been reported before, although it may seem an obvious possibility (Figure 4). The more distal insertion of the left phrenicoabdominal in close proximity to the left renal vein insertion on the CVC (Figure 2) and the presence of tumor means that the caudal CVC tourniquet often has to be placed distal to the left renal vein insertion, therefore also requiring right and left renal vein tourniquets to create a blood-free field during the CVC venotomy for left-sided tumors. In contrast the more cranial right phrenicoabdominal vein insertion (Figure 2) means that two CVC tourniquets cranial and caudal to the tumor thrombus in the CVC will usually suffice for right-sided tumors (Figure 3). One dog with a post-hepatic CVC thrombus required extension of the surgical approach to include a median sternotomy and six vascular tourniquets to additionally isolate the thoracic post-hepatic CVC and hepatic inflow (portal vein and hepatic artery).

Previous studies report closure of the CVC venotomy using a partial occlusion clamp,[1,2,4] whereas in others the CVC venotomy and closure was performed under full occlusion,[5,6] although the reason for selection of either technique is not clear. In this study both methods of CVC venotomy closure were used, with the venotomy being sutured under full occlusion if the venotomy was too large to accommodate a tangential clamp or if the positioning of the clamp was impractical. For right-sided tumors, the cranial insertion of the right phrenicoabdominal vein and subsequent proximity of the venotomy to the hepatic hilus (Figure 2) precluded easy clamp placement in some cases. Despite pre-placement (prior to venotomy) of the starting knot, performing the venotomy and vein closure under full CVC occlusion resulted in a longer median CVC occlusion time compared to using a partial occlusion clamp although this method appeared to be equally well tolerated.

Use of various suture sizes (4-0 to 5-0), material (silk, polypropylene, polydioxanone) and patterns (simple continuous, cruciate continuous) have been reported in the literature for performing the CVC venotomy closure.[1,2,4-6] This study did not differ much in this respect, although the suture line was oversewn with a second simple continuous suture pattern (6/19 dogs) if felt necessary at the discretion of the surgeon.

Authors of one study found a significantly higher risk of perioperative mortality if concurrent ureteronephrectomy was required as it indicated a larger, more invasive tumor,[7] although ureteronephrectomy has not been identified as a risk factor in other studies.[3] In this study ureteronephrectomy was performed in 5/19 dogs (26%) because of neoplastic invasion of the renal vein/kidney (Figure 5) or intra-operative damage to the left renal vein because of close proximity of the tumor. Knowledge that ureteronephrectomy was only performed with left-sided tumors in this study is useful for preoperative surgical planning and discussion with owners. Among the four dogs that died in the peri-operative period, one dog had a ureteronephrectomy performed and it is not possible from our limited data to evaluate if ureteronephrectomy is a risk factor for mortality in dogs undergoing adrenalectomy.

Information in the literature on the presentation and treatment of the most extensive adrenal tumor CVC thrombi is very limited. One study reported the extent of adrenal tumor CVC thrombus as a risk factor for perioperative mortality, with an overall mortality rate of 72% for 14 dogs undergoing CVC venotomy and 100% mortality for the seven dogs with a CVC thrombus extending beyond the hepatic hilus.[3] This contrasts with the results of this study where all five dogs with a thrombus extending to the hepatic or post-hepatic CVC survived to discharge. The overall 21% (4/19 dogs) mortality rate in this study is similar to other studies involving venotomy,[1,2,11] and all four dogs that died had pre-hepatic tumor thrombi. Successful outcomes for a number of dogs in this study were dependent on the availability of blood products, and all were dependent on receiving specialist anesthesia and critical care. The results of this study overall supports attempting surgical resection of many different types of invasive adrenal tumors, especially given the excellent long-term outcome expected from the published literature if the peri-operative period is survived.[1-7] However, owners should be made fully aware of the risks and complications.

The intra-operative (14/19 dogs, 74%) and post-operative (13/18 dogs, 72%) complication rates in this study were high, which is similar to other studies.[1-7,10] The types of complications reported are also similar, including surgical hemorrhage, anesthetic complications, pancreatitis, azotemia/renal failure and thromboembolic complications.[1-7] Very limited information is available regarding anticoagulation strategies for the prevention or treatment of thromboembolic disease in canine patients undergoing adrenalectomy with venotomy, despite pheochromocytoma, venotomy and blood transfusion all being reported as factors that increase the risk of disseminated intravascular coagulation in dogs undergoing adrenalectomy.[3] In contrast to the single pre-venotomy heparin dose given in this study, one study reports the administration of heparin in plasma during surgery with continued heparin doses tapering over several days,[2] but there are no studies reporting decreased incidence of thromboembolism with any anticoagulation protocol. Application of a topical anticoagulation solution (ice-cold lidocaine, heparin and saline) to thoroughly flush a venotomy site prior to closure is recommended in one surgical textbook.[12] One uncommon complication seen in this study was temporary jejunal ischemia due to occlusion of the cranial mesenteric artery in two dogs during dissection of large left sided tumors that enveloped this artery. The ligature was removed in both cases reversing the problem but necessitating a longer dissection to preserve this artery. This problem was anticipated prior to surgery as the cranial mesenteric artery was seen to be enveloped by the left sided adrenal tumor on computed tomography (Figure 6) . Discoloration of the small intestine during adrenal tumor dissection without the cause identified has been mentioned in two other studies, one as a temporary event where the dog recovered[11] and one in which fatal permanent jejunal necrosis was described.[10]

This study had substantial limitations. Because of the retrospective nature, the sample size, completeness and type of data collected could not be controlled, and there was a smaller population of dogs with CVC thrombi extending beyond the hepatic hilus compared to those within the pre-hepatic CVC. The surgeries in this study, although from one institution, were non-standardized and performed by multiple board-certified surgeons and anesthesiologists. Multi-institutional prospective studies with predefined surgical, anesthesia, endocrine, and anticoagulation protocols would substantially enhance the power and quality of the data that could be captured regarding surgical treatment of adrenal tumors with CVC invasion in dogs.

In conclusion, CVC occlusion times up to eight minutes appear to be well tolerated in clinical cases of dogs undergoing adrenalectomy with CVC venotomy, similar to that reported in experimental healthy dogs, and additionally longer CVC occlusion times may also be well tolerated in some clinical cases. In contrast to other reports, dogs with CVC tumor thrombi extending beyond the hepatic hilus can survive the perioperative period. The variation in presentation of adrenal tumor thrombi and the details of surgical techniques used to treat them in this study, particularly the differences between right and left sides, provides useful additional information for surgeons planning and operating on these types of cases. Pre-operative planning is particularly important to minimize surgery time in these types of cases that are at risk of unstable anesthetics and may need a long or difficult dissection to remove the adrenal tumor, although the venotomy aspect of the procedure is very controlled and always relatively short in relation to the rest of the surgery.

**Disclosure Statement**

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

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**Figure Legends**

Fig 1. Adrenal tumors typically extend down phrenicoabdominal (PA) vein and into caudal vena cava but do not adhere to the walls of the cava itself.

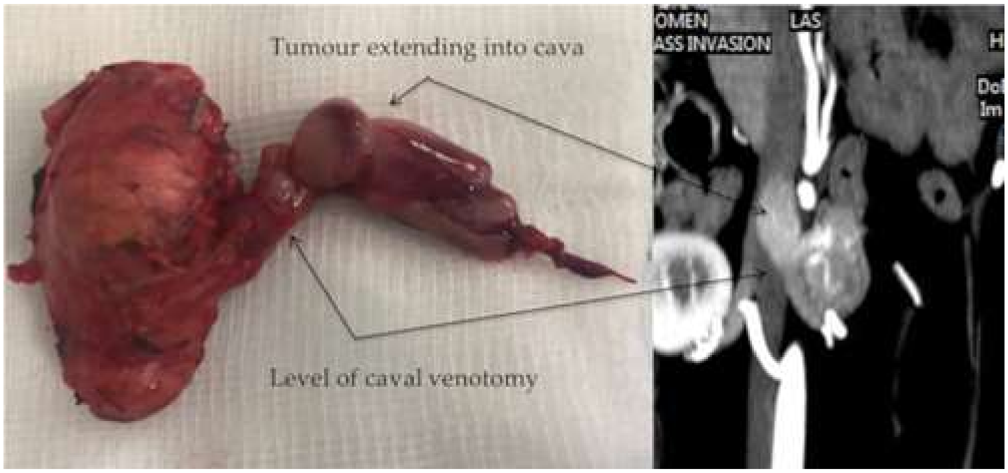


Fig 2. Illustrations show the more distal insertion of the left phrenicoabdominal (PA) vein adjacent to the insertion of the left renal vein on the caudal vena cava (CVC) and the proximity of the right PA vein to the hepatic hilus.

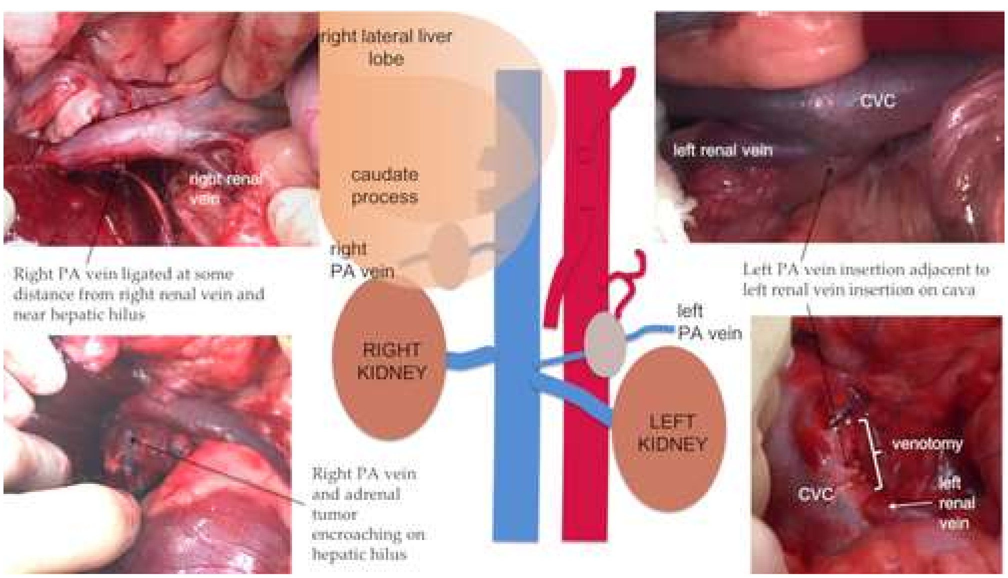

Fig 3. Right sided adrenal tumors with caval extension usually only need 2 tourniquets to isolate them. The right adrenal tumor has been dissected out until it only remains attached by the right phrenicoabdominal (PA) vein insertion on the caudal vena cava (CVC).

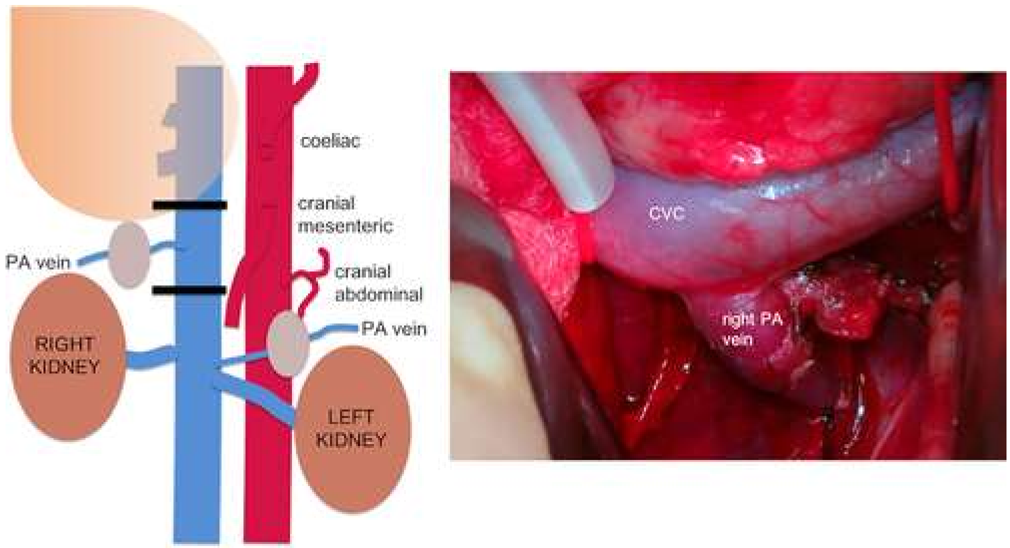

Fig 4. Left sided adrenal tumors with caval extension usually require 3 to 4 tourniquets to isolate them. After dissection of the left adrenal tumor it is passed underneath the mesentery so as to be on the same side as the caudal vena cava (CVC) to facilitate final exposure for the venotomy.

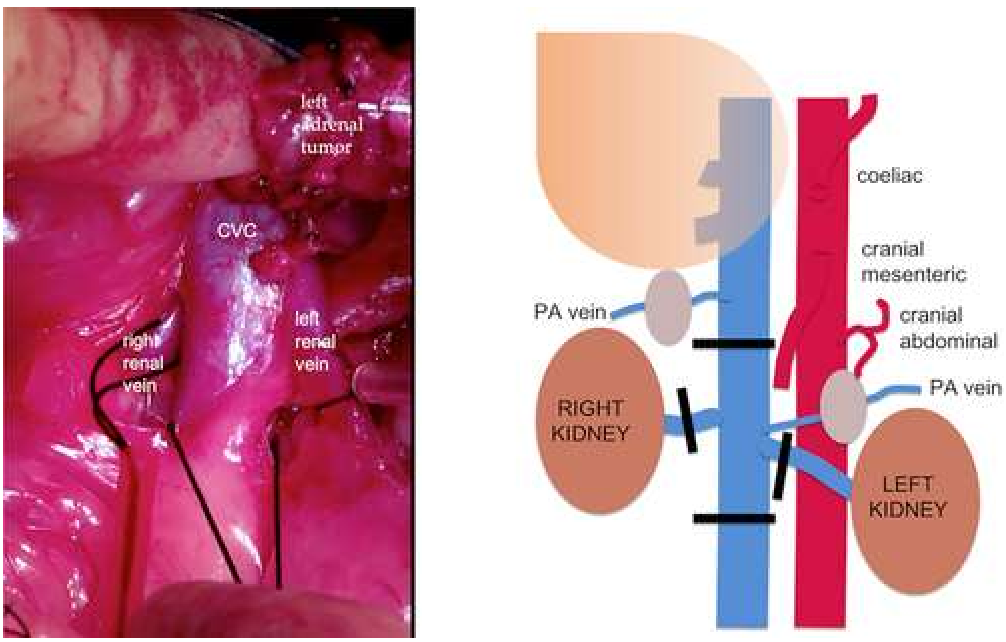

Fig 5. Left adrenal tumor compressing/invading left renal vein. A left reteronephrectomy was planned from the outset in this case.

Fig 6. Left adrenal tumor enveloping cranial mesenteric artery.