

# Use of hemostatic material on the damaged renal artery and caudal vena cava during adrenalectomy: A case study of two dogs

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Received 19.06.2025

Accepted 14.07.2025

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### Summary

This retrospective article presents two canine case studies involving complications during adrenalectomy, where intraoperative damage occurred to the caudal vena cava and renal artery. The authors explore the successful use of TachoSil, a collagen-based hemostatic patch with human fibrinogen and thrombin, as a non-suturing alternative to control bleeding from small vascular injuries. In both cases – a Jack Russell terrier with a hormonally active right adrenal tumor and a Yorkshire terrier with a non-functional left adrenal tumor – adrenal masses compressed adjacent vascular structures. During dissection, minor tears occurred in the vessels. Instead of traditional suturing, TachoSil was applied, resulting in immediate and stable hemostasis without hemodynamic compromise, thrombosis, or organ dysfunction. Postoperative monitoring confirmed normal renal function and absence of hemorrhage. The authors discuss the limitations and complications of suturing major vessels, such as thrombosis, stricture, and hemorrhage, and advocate the selective use of TachoSil for minor injuries. They emphasize the importance of meticulous anesthesia management and multimodal analgesia during adrenal surgery to prevent perioperative complications. The study concludes that TachoSil is a safe and effective alternative for managing small vessel injuries during adrenalectomy in dogs, potentially reducing the need for more invasive interventions like nephrectomy or vascular suturing.

**Keywords:** adrenal tumor, hemostatic agent, TachoSil, vascular injury, canine surgery

Primary adrenal tumors are rare but quite well-recognized conditions in veterinary medicine (10). They are most commonly described in dogs, horses, and cattle but have also been documented in numerous other domestic and exotic animal species (14, 32). The clinical and pathological features of these tumors in dogs share similarities with those in human cases (18). Adrenal tumors are neuroendocrine tumors arising from chromaffin cells of the adrenal medulla in dogs (17). These tumors are reported to account for 1% to 2% of all neoplasms in dogs. Tumors originating from the adrenal cortex are generally classified as adrenocortical carcinomas (ACCs) or adenomas and

may produce steroid hormones, including androgens, aldosterone, and cortisol (33). Primary adrenal tumors originating from the cortex are classified as malignant, with potential complications including invasion of nearby blood vessels, hemorrhage around the adrenal glands, compression of surrounding abdominal structures, and metastatic spread (4, 33). Adrenal-dependent hyperadrenocorticism (ADH) is uncommon, which is why they are responsible for 10-20% of the naturally occurring Cushing's syndrome diagnosed in dogs (43). They typically present unilaterally (approximately 90%), although simultaneous occurrence with other endocrine tumors has been reported (7). If any symp-

Tab. 1. Comparison of hemostatic agents in veterinary and human surgery (1, 8, 12, 24, 26)

| Class                 | Examples (Veterinary)               | Examples (Human)                                                         | Mechanism of Action                         |
|-----------------------|-------------------------------------|--------------------------------------------------------------------------|---------------------------------------------|
| Caustic               | –                                   | Aluminum chloride, Monsel's solution (ferric subsulfate), Silver nitrate | Protein coagulation at bleeding surface     |
| Mechanical            | Gelfoam, Surgicel, Instat, Bone wax | Gelfoam, Surgicel, Avitene                                               | Physical barrier, platelet matrix formation |
| Biologic              | Collagen + thrombin (Instat)        | Topical thrombin, fibrin sealants (e.g., Tisseel, TachoSil)              | Activation of coagulation cascade           |
| Impregnated Dressings | Chitosan, kaolin (field use)        | QuikClot, Hemcon, XSTAT                                                  | Factor XII activation, mechanical sealing   |
| Systemic              | –                                   | Fresh Frozen Plasma (FFP), Desmopressin, Vitamin K                       | Replenish or stimulate coagulation factors  |

toms appear at all, they are most commonly episodic hypertension, tachycardia (attributable to excessive and unregulated catecholamine secretion from functional tumors), weakness, and abdominal pain (17). While urine catecholamine testing can aid in the diagnosis of some pheochromocytomas, diagnostic image techniques and histopathologic assessment remain the definitive methods for adrenal tumor diagnosis (20). A correct diagnosis should be based on combining information from radiographic studies, abdominal ultrasound, computed tomography (CT), or magnetic resonance imaging (MRI) (5, 15). These tools only allow for the localization of the tumor, its size, and its estimated mass. Histological analysis, including vascular and capsular invasion, growth pattern, necrosis, intratumoral fibrosis, pleomorphism, hemorrhage, calcification, mitotic index, nuclear grade, atypical mitotic figures, abnormal nuclei, and cytoplasmic eosinophilia (29, 47), is also necessary for a sample taken from the tumor. Differentiating between an adenoma and a carcinoma is often very challenging (29). Regardless of the tumor origin, adrenalectomy is required for a definitive diagnosis and treatment in dogs with primary adrenal tumors (37).

A wide range of hemostatic agents are used in both veterinary and human medicine (Tab. 1). These include mechanical hemostats such as gelatin sponges (e.g., Gelfoam), cellulose-based materials (e.g., Surgicel), and collagen-based sponges (e.g., Instat), which absorb blood and exert localized pressure, thereby enhancing hemostasis (8). Bone wax is also commonly and effectively employed for this purpose (11). Active biological hemostatic agents contain thrombin and collagen, promoting coagulation by enhancing platelet aggregation (1, 24). Additionally, the use of impregnated dressings has been documented in the literature as a viable option (12, 26). In some cases, surgeons may also place a mesh to help control bleeding and support wound healing (42).

TachoSil is an active, biologically derived hemostatic agent. It is composed of equine collagen coated with fibrinogen and thrombin. Upon contact with blood or other bodily fluids, thrombin converts fibrinogen into fibrin, leading to the formation of a fibrin clot that seals the bleeding surface (41, 49).

Adrenalectomy, performed to treat primary adrenal tumors, has been associated with a wide range of poten-

tially serious complications (13, 45). These include excessive bleeding, including bleeding caused by surgical rupture of the vessels, blood pressure instability (both hypotension and hypertension), cardiac arrhythmias, oxygen deprivation, clotting abnormalities, respiratory complications, inflammation of the abdominal lining, kidney dysfunction, gastrointestinal issues like nausea and diarrhea, pancreatitis, aspiration-related lung infections, and even fatal outcomes (4, 38). According to retrospective studies involving over 40 dogs, the risk of death around the time of surgery has been reported to vary between 1.5% and 26% (3, 4).

Adrenalectomy can be carried out using several surgical approaches, including ventral midline, paracostal, and intercostal methods (2). More recently, laparoscopic adrenalectomy has gained increasing attention (6). Numerous studies suggest that this minimally invasive technique yields favorable outcomes in treating companion animals, particularly when dealing with non-invasive adrenal tumors, compared to traditional surgical methods (52).

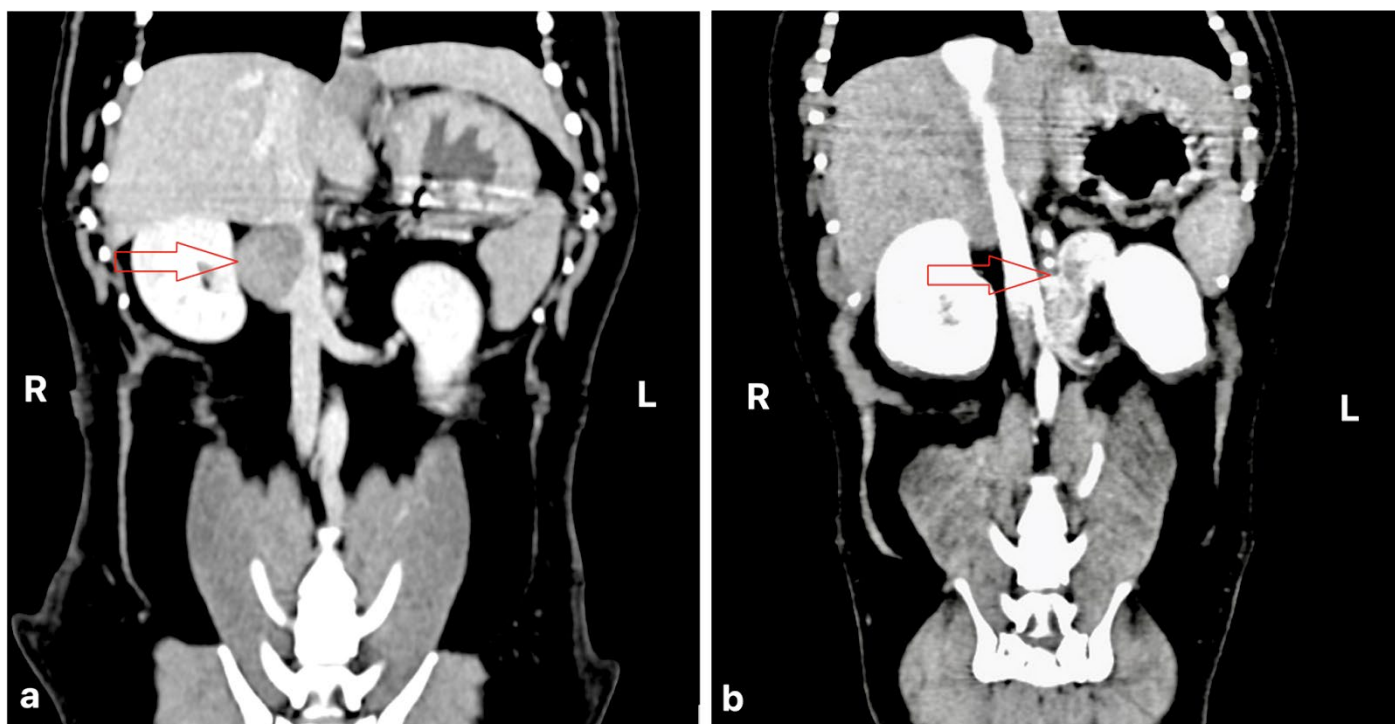
Adrenal tumors can be classified as either invasive – affecting nearby vessels such as the caudal vena cava and renal artery – or non-invasive (58). Although non-invasive tumors do not infiltrate surrounding blood vessels, the tumor capsule may adhere to the vascular adventitia (40). In such cases, there is a potential risk of vascular injury during surgical dissection (26). This article aims to report the clinical outcomes of applying a hemostatic agent to injuries of the caudal vena cava and renal artery encountered during adrenalectomy.

## Case presentations

Patients were referred to the Department of Surgery and Radiology with the Clinic for unilateral adrenalectomy (Tab. 2). In both cases, an adrenal tumor was diagnosed:

Tab. 2. Cases presentation

|                        | Dog 1                                                               | Dog 2                                                                                                          |
|------------------------|---------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|
| Dog breed              | Jack Russell terrier                                                | Yorkshire terrier                                                                                              |
| Age                    | 11 years                                                            | 10 years                                                                                                       |
| Indication for surgery | Hormonally active right adrenal tumor showing hyper adrenocorticism | Hormonally inactive left adrenal tumor causing pain symptoms due to the mass effect on the surrounding tissues |
| Current treatment      | Analgesia, trilostan                                                | Analgesia                                                                                                      |



**Fig. 1. a)** Computed tomography examination of the abdominal cavity of Dog 1. In the region of the right adrenal gland, a focal, homogeneous, oval, well-defined pathological mass with smooth margins is visible, measuring approximately 2 cm CrCd  $\times$  2.7 cm DV  $\times$  2 cm RL. At the cranial pole of the mass, a small (approximately 1 cm), irregularly shaped mineralization is observed. The pathological mass is in close proximity to the right renal vein, causing slight compression without signs of vascular infiltration. Additionally, dorsally, the mass compresses the caudal vena cava, reducing its diameter by approximately 50% at the point of greatest compression, again without signs of vascular infiltration. Cranially, the pathological mass is in contact with the caudate lobe of the liver, with no signs of invasion into the hepatic tissue. The red arrow indicates the pathologically altered adrenal gland. **b)** Computed tomography examination of the abdominal cavity of Dog 2. The left adrenal gland is irregular and enlarged, measuring approximately 3.5 cm CrCd  $\times$  1.5 cm DV  $\times$  9 mm LR. It is located in close proximity to the abdominal aorta, without signs of vascular invasion. The medial wall of the caudal vena cava is in contact with the focal mass, most likely without evidence of vessel infiltration. The renal vein lies at the caudal pole of the pathological mass and runs along its dorsomedial border; the mass molds it but shows no signs of vascular invasion. The red arrow indicates the pathologically altered adrenal gland (16-row Tomography Machine Siemens Somatom Go.Now, Germany)

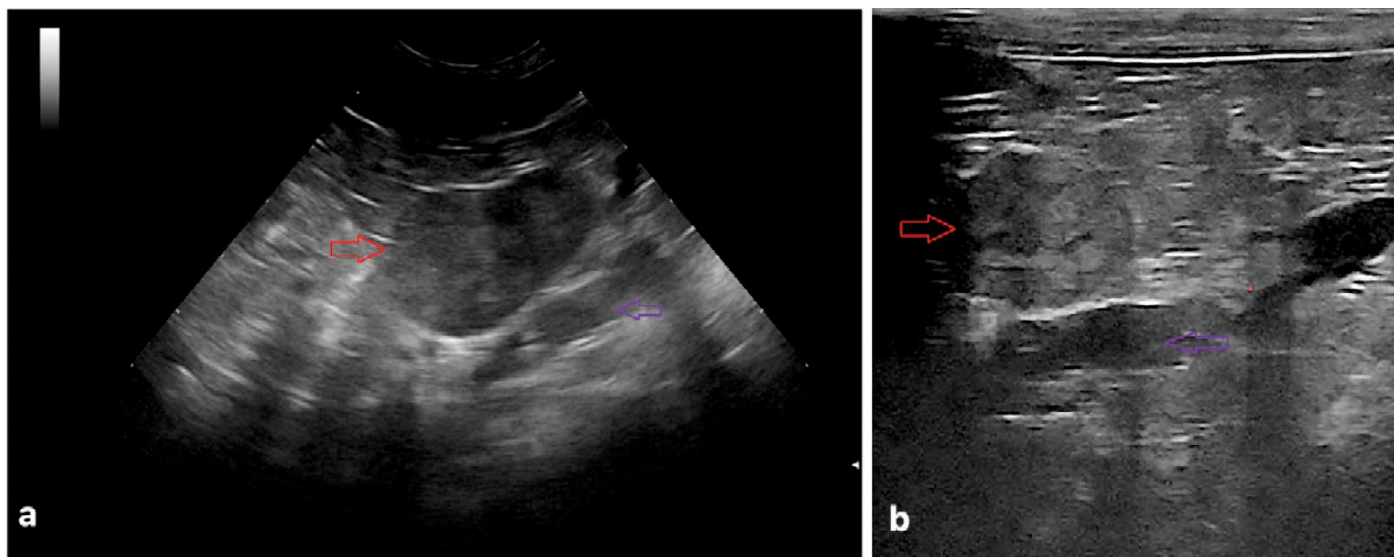
a right adrenal tumor in Dog 1 and a left adrenal tumor in Dog 2. To facilitate precise surgical planning, the patients underwent diagnostic imaging, including computed tomography (CT) and ultrasonography (USG) (Fig. 1, 2).

Before surgery, dogs were given maropitant (Zoetis, Belgium) at 1 mg/kg IV and metamizole (Biowet, Poland) at 50 mg/kg IV (slow injection) and premedicated with atropine (Polpharma, Poland) at 20  $\mu$ g/kg SC, followed by methadone (Dechra, Holand) at 0.2 mg/kg IV and midazolam (Dechra, Holand) at 0.2 mg/kg IV. Preoxygenation was performed using 100% oxygen at a flow rate of 4 L/min for 5 minutes. General anesthesia was induced using lidocaine (Polpharma, Poland) (1.5 mg/kg), fentanyl (Dechra, Holand) (2  $\mu$ g/kg IV), and alfaxalone (Zoetis, Belgium) (1 mg/kg IV). The trachea was intubated with a low-volume, high-pressure silicone endotracheal tube and then connected to a pediatric anesthetic breathing system. The patient was allowed to breathe spontaneously, and a stable depth of anesthesia (absence of palpebral reflex, ventromedial eye rotation, and absence of jaw tone) was targeted using isoflurane (Vetpharma, Spain) (Fe 1-1.3%) in oxygen combined with IV lidocaine (2 mg/kg/hour), maropitant (100  $\mu$ g/kg/hour) and fentanyl (15  $\mu$ g/kg/hour) continuous rate infusions (CRI). After induction and connection of isoflurane,

the transversus abdominis plane (TAP) block was administered using 0.25% ropivacaine (Fresenius, Swiss) 0.2 ml/kg, injected at each point. During the procedure, patients were monitored using invasive blood pressure measurement, non-invasive oscillometric arterial blood pressure measurement, a transmittance pulse oximeter, side-stream capnography, esophageal temperature measurement, and a cardiac monitor (a three-lead ECG).

The surgical approach for both patients was through the midline, from the xiphoid process to the pubic symphysis. The abdominal wall was incised, and then the falciform ligament was cut to improve the visibility of the surgical field. Two maneuvers were performed to expose the adrenal glands: the duodenal maneuver for the right adrenal gland and the colonic maneuver for the left adrenal gland. The neoplastic mass of right adrenal tumor in Dog 1 had reached a significant size and was compressing the caudal vena cava. Although no apparent infiltration was observed on the computed tomography scan, during tissue dissection, it became apparent that the serosal layer of the tumor and the adventitia of the caudal vena cava adhered to each other. The dissection began by exposing the right phrenicoabdominal vein, which was then ligated. The left pole of the tumor, distal to the adhesion with the caudal vena cava,





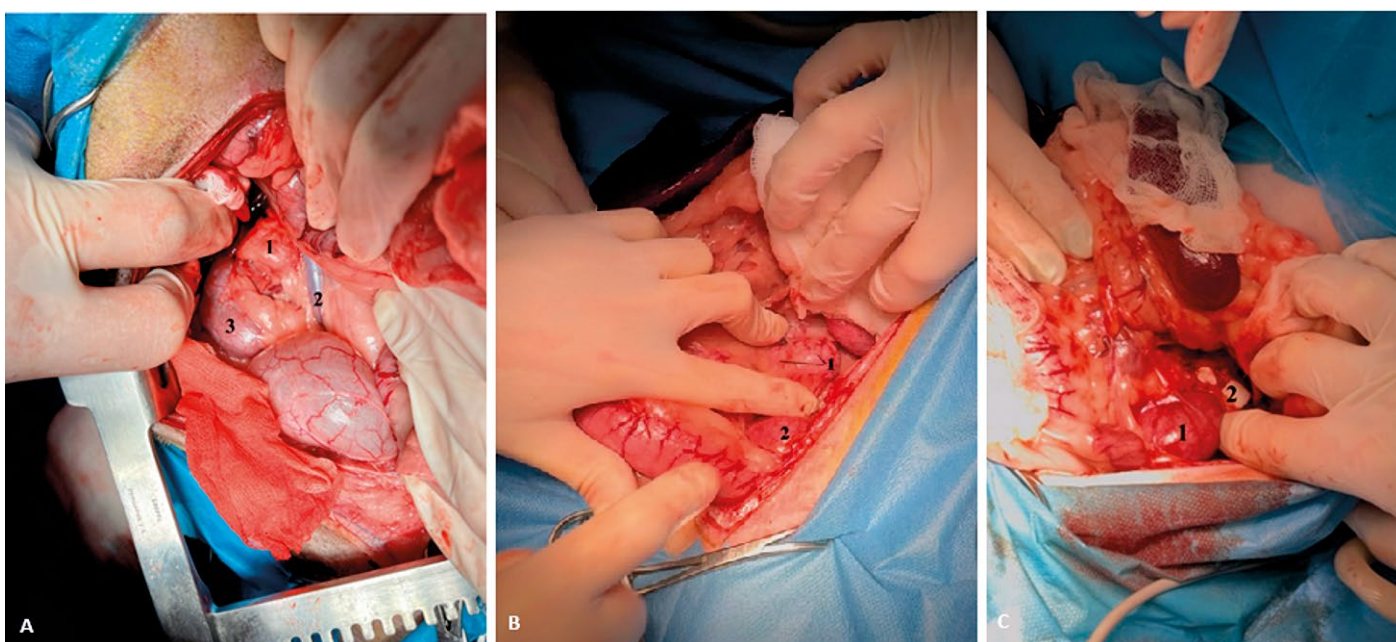
**Fig. 2.** a) Ultrasound examination of the abdominal cavity of Dog 1. The red arrow indicates the pathologically altered adrenal gland. The purple arrow points to the right renal artery. The examination was performed with a convex probe. b) Ultrasound examination of the abdominal cavity of Dog 2. The red arrow indicates the pathologically altered adrenal gland. The purple arrow points to the left renal artery. Test performed with a linear type of probe

was dissected. After the tumor was fully freed, the dissection of the adhesion between the tumor and the caudal vena cava was initiated. The right adrenal gland was removed entirely. During the surgical procedure, a vessel wall was damaged over a length of approximately 3 mm. A temporary occlusion was performed using a surgical tampon, followed by applying TachoSil – a hemostatic product containing fibrinogen and thrombin. No changes were observed in the patient's monitoring parameters.

The neoplastic mass of left adrenal tumor in Dog 2 also reached a significant size and was compressing the left kidney, including the left renal artery. The adrenalectomy was initiated by exposing and ligating the left phrenicoabdominal vein, followed by the dissection of the tumor from

the surrounding tissues, including the cranial serosa of the left kidney. During the dissection, the left renal artery, to which the smaller branch of the tumor was adhered, was damaged. A temporary occlusion was performed using a surgical tampon, followed by the application of fragmented TachoSil. The kidney was then monitored for any changes in color or signs of ischemic necrosis. No changes were observed in the organ's morphology or the patient's vital parameters.

After the procedure, the patients were under hospital care for 48 hours. During the hospitalization, abdominal ultrasonography with and without Doppler was performed thrice daily, and non-invasive blood pressure measurements were taken. Additionally, blood biochemical tests were conducted



**Fig. 3.** A. View of the midline approach to the right adrenal gland using the duodenal maneuver: 1 – right adrenal gland, 2 – right kidney, 3 – caudal vena cava; B. View of the midline approach to the left adrenal gland using the colonic maneuver: 1 – left adrenal gland, 2 – left kidney; C. View of the abdomen after left adrenalectomy: 1 – left kidney, 2 – TachoSil

to ensure that all parameters were within normal ranges. No active abdominal bleeding was observed in either of the patients. In Dog 2, no changes were observed in the morphology of the left kidney during the ultrasonographic examination, and the organ's function remained normal, as indicated by the blood biochemical tests, which showed no changes compared to preoperative levels (SDMA, urea, creatinine).

Postoperative care also included pain management and stabilization of any potential hypertension. Both dogs were administered intravenous methadone (Dechra, Holand) boluses every 8 hours at a dose of 0.2 mg/kg, and additionally, robenacoxib (Novartis, Switzerland) was given at a dose of 2 mg/kg. In Dog 1, hypertension was observed during the first 24 hours after the procedure, with an average reading of 160 mmHg. This symptom was treated symptomatically with enalapril (Boehringer Ingelheim Vetmedica, Germany) at a dose of 0.5 mg/kg. Both dogs were stable 48 hours after the procedure, so they were discharged to their home.

### Discussion

Vascular invasion is one of the factors contributing to high mortality in patients undergoing adrenalectomy. Tumor invasion into blood vessels is observed in pheochromocytomas and adrenocortical carcinomas. These tumors most commonly penetrate the caudal vena cava. Reports of invasion into the left renal artery or vein are less frequent, even though left adrenal tumors occur statistically more often (4, 19, 27, 28). In earlier studies, the mortality rate in tumors with vascular invasion was reported at 71% (4). In more recent literature, this rate is 21% (27, 45). The authors suspect the high mortality rate in previous years may have been due to limited access to evidence based knowledge.

There is a lack of detailed descriptions in the literature regarding surgical procedures involving venotomy of the caudal vena cava and tumor extraction from within the vessel. These procedures include vascular loops, partial or complete vessel occlusion, and venotomy closure (23, 27, 45). The literature also describes the suture materials used for venotomy closure. Various suture sizes from 4-0 to 5-0 have been used, with materials including silk, polypropylene, and polydioxanone. Suturing techniques employed for closing the caudal vena cava include continuous simple sutures and interrupted cruciate sutures (19, 23, 30, 37). The literature does not provide information on the use of hemostatic agents during vessel injury during surgical dissection in adrenalectomy. The authors recognize that hemostatic material is unsuitable for more extensive vascular damage or in cases of invasive adrenal tumors. However, the authors suggest using hemostatic agents instead of surgical suturing for smaller vessel injuries with disruptions ranging from 1 mm to 3 mm in width. Suturing major blood vessels such as the posterior (caudal) vena cava and renal artery carries significant risks. Complications can arise from technical errors, anatomical challenges, or

postoperative factors. Complications of suturing the CVC include thrombosis and stricture, hemorrhage, and arteriovenous fistula (AVF) formation (22, 25, 43). Improper suturing can lead to narrowing (stricture) of the vena cava, resulting in impaired blood flow and thrombosis. In a canine case, inadvertent transection and repair of the caudal vena cava led to mild pelvic limb edema and suspected stricture, with collateral circulation developing over time (22). Additionally, inadequate hemostasis or suture dehiscence can cause significant bleeding. Early postoperative hemorrhage may necessitate prompt surgical intervention to control bleeding and prevent thrombosis due to extrinsic compression (25). Thrombosis may also occur in the renal artery during surgical dissection. Technical errors during anastomosis can lead to renal artery thrombosis, compromising kidney perfusion (57). In addition, pseudoaneurysm and AVF formation may occur (31). All of the above are associated with organ ischemia and atrophy or necrosis (59). Therefore, for minor injuries, the use of hemostatic material is recommended to avoid introducing foreign material into the vessel.

Nephrectomy is another factor contributing to high mortality in adrenalectomy procedures (48). The necessity for nephrectomy during adrenal gland tumor removal often arises when the tumor invades or compresses the adjacent renal structures, making it impossible to achieve complete resection without sacrificing the kidney. It has been demonstrated that combining adrenalectomy with nephrectomy significantly reduces patient survival time (37). This combination increases surgical complexity and places additional physiological stress on the patient (55). Removal of the kidney may lead to several critical consequences. One of the most significant is the risk of acute renal failure in the remaining kidney, primarily if pre-existing renal compromise or hypoperfusion occurs intraoperatively. Loss of one kidney also reduces the animal's overall renal reserve, which may predispose to chronic kidney disease or exacerbate any existing renal dysfunction. Furthermore, nephrectomy extends the duration of surgery and anesthesia, both of which are independent risk factors for postoperative complications and poor outcomes, particularly in geriatric or systemically compromised patients (28, 30). Additionally, intraoperative blood loss may be increased during combined procedures, necessitating more aggressive fluid and transfusion support. Postoperative recovery can also be prolonged, with an increased risk of infection, delayed wound healing, and systemic decompensation. These cumulative risks contribute to a markedly guarded prognosis when adrenalectomy is accompanied by nephrectomy, underscoring the importance of careful preoperative planning and intraoperative decision-making to preserve renal function whenever feasible (45). In the case of Dog 2, the surgeon had two additional surgical options: either to remove the kidney or to perform suturing of the renal artery. Due



to the circumstances, nephrectomy was not performed. Instead, TachoSil was applied to the tissues with subsequent organ observation to monitor for signs of necrosis (macroscopic evaluation of kidney color, serosal structure, and kidney shape).

Among the many available hemostatic agents, the surgeon chose to use TachoSil. It's a collagen-based hemostatic patch coated with human fibrinogen and thrombin. Upon application to a bleeding surface, the thrombin converts the fibrinogen into a fibrin clot, promoting rapid clot formation and the patch's adhesion to the tissue. The collagen matrix provides mechanical stability, while the biological components stimulate the coagulation cascade, achieving a dual hemostatic effect – both mechanical and biochemical (36, 50). Therefore, it can be successfully used in cases of minor vessel damage during adrenalectomy. Thanks to its adhesive properties and rapid onset of action, it effectively controls bleeding from high-pressure vessels – in this case, the caudal vena cava and the renal artery. Stopping the hemorrhage and providing active components supports the body's natural regenerative processes. TachoSil is generally well-tolerated and biodegradable, absorbed within 12 weeks post-application without inducing significant inflammation or fibrosis. This makes it particularly safe for use in sensitive areas (36, 46). Unlike suture repairs or synthetic glues, TachoSil's localized action limits systemic exposure to coagulation factors, significantly reducing the risk of thromboembolism. This is crucial in vascular applications, especially in dogs with underlying endocrine conditions like hyperadrenocorticism, where coagulopathies are common (53). Compared to other topical hemostatic agents, TachoSil offers several advantages in both human and veterinary surgery. Unlike oxidized regenerated cellulose (e.g., Surgicel), which acts solely as a mechanical barrier, TachoSil combines a collagen sponge with human fibrinogen and thrombin to promote mechanical sealing and active coagulation (46). This dual mechanism allows for faster and more reliable hemostasis, particularly in areas with active bleeding. Gelatin-based agents like Gelfoam or FloSeal are effective for diffuse oozing (50). Still, they may swell post-application, posing a risk of compression in confined spaces, which is less of a concern with TachoSil due to its minimal expansion. Furthermore, fibrin glues (e.g., Tisseel) provide sound hemostatic effects but are more technically challenging to apply precisely, especially on curved or mobile surfaces. In contrast, TachoSil adheres easily to wet tissue and remains in place without sutures or external pressure (46, 53). This makes it particularly suitable for controlling bleeding from vascular structures, such as the caudal vena cava or renal artery, where direct suture repair may be risky or infeasible. In our cases, no postoperative hemorrhage, thrombosis, or renal dysfunction was observed. TachoSil did not interfere with renal blood

flow when applied over the renal artery, nor did it affect venous return through the caudal vena cava.

Another important aspect that the authors draw attention to is the anesthetic procedure during adrenalectomy. Anesthesia of such a patient is associated with many challenges and potential complications. Understanding these aspects is crucial for ensuring patient safety and the overall success of the procedure.

During anesthesia, severe hemodynamic disturbances and fluctuations in blood pressure can occur. In dogs with pheochromocytoma, excessive catecholamine secretion can cause hemodynamic instability (9, 51). Studies have noted that preoperative administration of alpha-blockers, such as phenoxybenzamine, can help stabilize hemodynamics.

Other serious complications that may occur during the procedure are cardiac arrhythmias. The previously mentioned phenoxybenzamine has no direct effect on intraoperative arrhythmias in dogs (23), but it can cause reflex tachycardia due to the inhibition of pre-synaptic alpha-2 blockade, which often requires the preoperative use of beta-blockers. Such treatment has been described in human medicine (51).

Surgical manipulations necessary to remove the tumor may cause intraoperative hypertension. Available literature describes the treatment of hypertension with phentolamine (23, 28), esmolol (16), sodium nitropruside (28, 30, 34), acepromazine or higher concentrations of inhalation anesthetics (16, 56) or MgSO<sub>4</sub> (34). Accompanying tachycardia is usually treated with esmolol (16, 28).

Hypotension is a frequently reported complication following adrenal gland removal (23). This disorder is caused by the persistent effects of vasodilators and a decrease in ketecholamine levels (21). To counteract the drop in blood pressure, consider administering vasoconstrictors such as phenylephrine, ephedrine, dopamine, or dobutamine (28, 37) or crystalloid or colloid boluses (35).

Pressure spikes, hypertension observed during tumor removal and hypotension described after removal, may be caused by sympathetic stimulation and catecholamine release in response to pain. Therefore, multimodal analgesic action is important. For this purpose, continuous infusions of fentanyl, lidocaine, regional fascia blocks of the transverse abdominis muscle using ropivacaine, and epidural anesthesia using opioid drugs such as morphine or methadone are used (39). The above methods can be used separately or in combination.

In the cases presented in the article, no previous pharmacological therapies using selective blockers were used to ensure proper hemodynamics during the procedure. Continuous infusions of fentanyl lidocaine and additionally maropitant were used for pain therapy, and a transverse blockade was also used. Balanced fluid therapy (3 ml/kg/h) was conducted using crystalloid rich in sodium, potassium, calcium, chlorine ions and

a small addition of glucose. During the procedure, all vital parameters were meticulously monitored.

At the key moment of the procedure, no sudden jumps in blood pressure were observed. During tumor preparation, the patients were hemodynamically stable, and no arrhythmias or painful stimulation were detected. No techniques requiring complete or partial occlusion of blood vessels were used to remove the tumor. The bleeding was controlled using the hemostatic material TachoSil. It can be hypothesized that choosing a less invasive surgical method contributed to maintaining normal vital parameters during the entire anesthesia and the complete success of the procedure.

There is no doubt that this method requires further research. However, it currently yields very promising prognoses.

Although scientists have conducted numerous studies and published various results, developing an optimal anesthetic protocol for adrenal gland removal in dogs remains a challenge. The reason can be attributed to the complexity of the anesthetic administration process. This process requires detailed planning and monitoring. Proper preparation, the use of appropriate medications, and careful management of vital signs are crucial in minimizing the risk of complications and enhancing postoperative outcomes. Further research in this area is necessary to optimize anesthetic protocols and increase patient safety.

**Conclusions:** TachoSil demonstrates an excellent balance of efficacy and safety, particularly for small to moderate vascular injuries where suturing poses risks or technical challenges. Its biocompatibility, ease of use, and reliable hemostatic effect make it a superior choice among topical agents in delicate surgical settings such as adrenalectomy. Compared to other hemostatic materials, TachoSil's combination of biochemical activation and physical sealing provides more effective and localized hemostasis, especially in areas with high vascular tension or complex anatomy.

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