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Comparison of median sternotomy closure-related complication rates using orthopedic wire or suture in dogs: A multi-institutional observational treatment effect analysis

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Abstract

Objective: To determine and compare median sternotomy (MS) closure-related complication rates using orthopedic wire or suture in dogs.

The study was presented at European College of Veterinary Surgeons meeting 2021(online) as Resident forum presentation.

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Study design: Multi-institutional, retrospective observational study with treatment effect analysis.

Animals: 331 client-owned dogs, of which 68 were excluded.

Methods: Medical records of dogs with MS were examined across nine referral centers (2004–2020). Signalment, weight, clinical presentation, surgical details, complications, and outcomes were recorded. Follow-up was performed using patient records and email/telephone contact. Descriptive statistics, treatment effect analysis and logistic regression were performed.

Results: Median sternotomy closure was performed with wire in 115 dogs and suture in 148. Thirty-seven dogs experienced closure-related complications (14.1%), 20 in the wire group and 17 in the suture group. Twenty-three were listed as mild, four as moderate and 10 as severe. Treatment effect analysis showed a mean of 2.3% reduction in closure-related complications associated with using suture versus wire (95% CI: −9.1% to +4.5%). In multivariable logistic regression, the only factor associated with increased risk of closure-related complications was dog size ($p = .01$). This effect was not modified by the type of closure used (interaction term: OR = 0.99 [95% CI: 0.96/1.01]).

Conclusion: The incidence of closure-related complication after MS was low compared to previous reports. The likelihood of developing a closure-related complication was equivalent between sutures and wires, independent of dog size, despite a higher proportion of complications seen in larger dogs (≥20 kg).

Clinical significance: Use of either orthopedic wire or suture appear to be an appropriate closure method for sternotomy in dogs of any size.

1 | INTRODUCTION

Median sternotomy (MS) provides access to the entire thoracic cavity and is often the method of choice for thoracic exploratory surgery.[1–3] The surgical approach carries its own risks and complications regardless of the underlying reason for surgery. The method of closure following MS has been the subject of several studies attempting to identify the technique that provides optimal stability with low risk of complications.[4–6] Although a comparison of complications following wire or suture closure has been performed in vivo on research dogs,[4] there are currently no published comparisons of outcome following different sternotomy closure methods in clinical veterinary patients, including large dogs. This potentially hinders informed decision-making regarding method of sternotomy closure.[4–6] Complications of MS closure have mostly been identified in large dogs, whereas small dogs are perceived to be less susceptible to complications, although no formal comparison is currently available.[2,5] Historically, orthopedic stainless-steel wire was considered the material of choice in veterinary medicine.[1–3] Orthopedic wire is biologically relatively inert and has high tensile strength, providing permanent stability to the sternum[4] but has been associated with complications such as pain, incisional swelling, seroma formation, hemorrhage, skin dehiscence, incisional infection, osteomyelitis, or implant failure.[1,4,5,7] The reported incidence of complications following MS in small animals ranges from 17% to 78%.[1,4,5,7,8] Conversely, complication rates of 0.5%–5% have been reported in humans.[4,9,10] Suitable alternatives to stainless-steel orthopedic wire have been investigated in humans.[11] Suture has been suggested as one alternative due to its ease of handling and absorbability, therefore reducing the incidence of inflammatory reactions, as well as being less traumatic.[12,13] Median sternotomy closure with suture has also been reported to be quicker than wire closure.[4] Another suitable closure method for sternotomy in dogs is crimped monofilament.[14] Stainless-steel wire has been suggested to be superior,[4] or similar to suture in generating stability of the sternum[15] even though it remains to be confirmed whether sternal stability is the only factor contributing to surgical site morbidity following MS.

Propensity scoring and treatment effect analysis are methods of comparing results between different treatments in observational studies that are increasingly used in human[16–18] and veterinary medicine,[19,20] when a randomized clinical trial is not possible. The results focus on treatment effect size rather than statistical "significance" and can take account of the likelihood of allocation to each treatment and of various covariables that might influence the outcome. Treatment effects analysis aims to compare outcomes following different, nonrandomly allocated treatments by treating the comparison as a "missing data" problem. Outcomes from the allocated treatment in real patients are admixed with the inferred outcomes, based on other patient characteristics, were the counterfactual treatment to have been given. The entire dataset is then analyzed to determine the amount of difference in the outcome of interest between treatments (and which has implicitly been conditioned on the other factors that may play a role in determining that outcome). Although slightly different in technical application, this methodology is closely related to "propensity scoring" methods of comparing results between different treatments in observational studies. A randomized clinical trial (RCT) provides the gold standard test of the comparative value of different therapies, and has been used in human medicine to compare sternotomy closure.[21] Unfortunately, RCTs cannot always be applied in veterinary practice for a number of reasons such as inadequate infrastructure, logistical support, cost, animal welfare, complex and time-consuming regulation or over-restrictive interpretation of results without evidence of subject benefit.[22] When this occurs, propensity scoring and treatment effects analysis provide an alternative, albeit second-best, option that can be applied to analyze observational data.[23–27] Importantly, the results that are generated in this sort of studies focus on the effect size (i.e., the difference in outcome) of the treatment rather than simple statistical 'significance'.

The purpose of this study was to determine and compare median sternotomy (MS) closure-related complications using orthopedic wire or suture in dogs. Our hypothesis was that the complication rate would be higher in MS closed with orthopedic wires compared to those with suture.

2 | MATERIALS AND METHODS

Medical records of dogs that underwent MS between January 1, 2004 and August 1, 2020 were retrospectively reviewed. Dogs were recruited from nine veterinary academic or private practice referral hospitals. Contributing surgeons were invited to search the medical records at their institutions and extract data of dogs meeting the inclusion criteria into a dedicated spreadsheet (Excel, Microsoft Corporation).

Case records were reviewed for information regarding signalment; bodyweight; clinical presentation; indication for MS; details of surgery; material (wire or suture) used for closure including size and pattern; intra- and postoperative complications; postoperative medical management and duration of hospitalization. Indication for MS was further subclassified as: pyothorax, mass removal, pneumothorax, trauma and others. All surgeries were performed by either a supervised surgery resident or board-certified surgeon. A particular emphasis was placed on recording postoperative complications potentially related to the closure method, such as seroma formation, wound dehiscence, infection, pain, and gait abnormalities. Dogs were designated to the wire or suture group based on the material selected by the attending surgeon for sternotomy closure. When available, information regarding whether the MS was full or partial (leaving the manubrium and/or xiphoid intact) was recorded. Dogs ≥20 kg were listed as large.

Dogs were excluded if the previously mentioned information was absent, the animal died prior to discharge, sternotomy had been conducted as an extension of a celiotomy incision, and if follow-up was less than 5 days postoperatively.

Follow-up was performed using patient medical records and/or email/telephone contact with the owner or referring veterinarian. Classification of complications was in accordance with the Accordion classification reported by Folette et al.[28] Complications were classified as mild when minor invasive procedures such as analgesia, antipyretics were required, and as moderate when pharmacological treatment with other drugs, such as antibiotics were used. Severe complications were all those requiring surgical intervention. A postoperative complication was classified as an adverse event associated with and attributed to surgical intervention in the time period after skin closure.[28] A surgical site infection was classified as an infection within 90 days of the operative procedure involving the skin, subcutaneous tissue and/or the deep soft tissues of the incision.[29] All suspected infections required confirmation with a positive bacterial culture.

2.1 | Data analysis

Data were reported as mean and standard deviation (SD) when normally distributed and as median and interquartile range (IQR) when nonparametrically distributed. Data was analyzed using descriptive statistics and logistic regression analysis. Due to the lack of randomization, treatment effects analysis (Stata 14 software, StataCorp) was used to quantify the difference in complication rates between closure methods. This method takes into account the likelihood of being allocated to specific treatment based on various patient factors (in this instance, weight, age, disease process and clinic) and also the possible effect of various patient factors (weight, age and disease process in the cohort studied within) in influencing the likelihood of the outcome (a surgical complication). Statistical analysis was performed using GraphPad Prism 7 (GraphPad Software) and Stata 14 (StataCorp).

3 | RESULTS

A total of 331 dogs which underwent MS were included in the study. Twenty-four dogs were subsequently excluded because a combination of wire and suture was used for closure of the sternum, and 44 due to insufficient follow-up time, leaving a total of 263 dogs for descriptive statistical and treatment effect analysis (Figure 1). Noteworthy is, that the wire group <20 kg included fewer dogs compared to the other three groups. Individual institutions contributed between 7 and 87 cases.

The median age at surgery was 72 months (IQR 39–169). There were 158 males (120 castrated and 38 intact) and 105 females (78 spayed and 27 intact). Breeds most represented were Labrador retrievers (n = 54); English springer spaniels (n = 42) and cross breeds (n = 33) (Table 1).

A total of 151 MS were noted as a partial sternotomy (77 in the wire group; 74 in the suture group), 33 as a partial sternotomy including xiphoid (14 in the wire group; 19 in the suture group), 22 as partial sternotomy including manubrium (12 in the wire group; 10 in the suture group), 54 as full sternotomy (9 in the wire group; 45 in the suture group). Three MS were marked as unknown to which type of sternotomy was performed.

The closure of MS was performed with wire in 115 (44%) dogs, and with synthetic suture in 148 (56%) dogs. Polydioxanone was used in 142 dogs, and nylon leader line (CCL pack, Veterinary Instrumentation) in six. Surgeon rationale for use of suture or wire for closure was listed as surgical preference or was not available.

Median hospitalization duration for all dogs was 5 days (IQR 4–7). More specifically, median hospitalization for the wire group was 6 days (IQR 4–8) and 5 days for the suture group (IQR 3–6). Hospitalization duration was unknown for four dogs in the wire group.

Median follow-up was 27 days (IQR] 11–256) for all dogs; 29 days (IQR 10–272) for the wire group; 26 days (IQR 10–225) for the suture group postoperatively (Table 2 and Figure 2). A total of 107 dogs were followed over 42 days postoperatively, 49 in the wire group and 58 in the suture group (Table 2).

Mean weight was 27.4 kg (SD 9.3) in the wire group and 21.4 kg (SD 10.1) in the suture group. The main underlying disease processes for all dogs were pyothorax (n = 90) and pneumothorax (n = 85), mass removal (including mediastinal, lung, abscesses) (n = 70) and traumatic injury (n = 11). Seven dogs were classified as

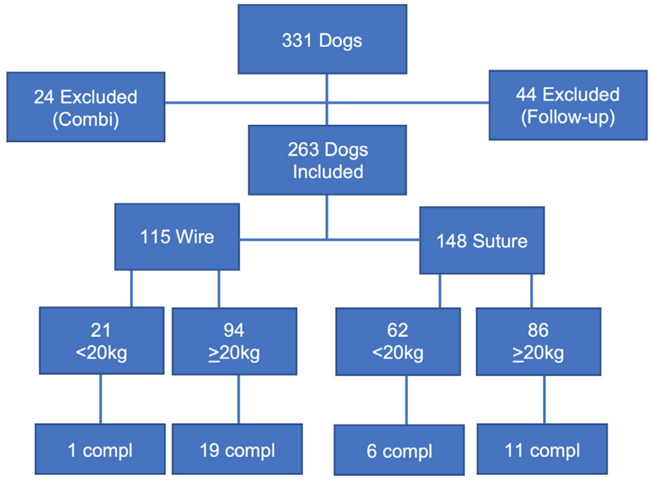

FIGURE 1 Flow chart illustrating case recruitment. Compl: complications; Combi: combination of wire and suture

TABLE 1 Dogs included in the study arranged by breed

Dog breeds	Number per breed
Labrador retriever	54
English springer spaniel	42
Cross breeds	33
German shepherd dog	18
English cocker spaniel	16
Lurcher	12
Golden retriever	11
Staffordshire bull terrier	7
Greyhound	6
Siberian husky, German shorthaired pointer	5
Border collie; Weimaraner	4
Jack Russell Terrier, Boxer	3
Yorkshire terrier, Bichon frisé, Dachshund, Sprocker spaniel, Great Dane, Poodle, Rhodesian ridgeback, Shih tzu, Whippet	2
Afghan hound, Alaskan Malamute, Petit Basset Griffon Vendéen, Beagle, Belgian shepherd Groenendael, Bernese mountain dog, Border terrier, Cavalier King Charles spaniel, Chihuahua, Doberman Pinscher, Dogue de Bordeaux, English bulldog, Flat-coated retriever, Gordon setter, Hungarian vizsla, Irish terrier, Italian Spinone, Leonberger, Old English sheepdog, Red setter, Schnauzer, West Highland White terrier.	1

TABLE 2 Distribution of follow-up times in dogs between weight categories (<20 and ≥20 kg) and MS closure method (wire vs. suture)

	Wire	Suture	Wire	Suture	Total (*N*)	Total (*N*)
Weight	**<20 kg**	**<20 kg**	**≥20 kg**	**≥20 kg**	**All weights and material**	**Complications**
Follow-up >5 days	21	62	94	86	263	37 (17 S; 20 W)
Follow-up >14 days	7	40	72	65	184	32 (15 S; 17 W)
Follow-up >42 days	6	25	43	33	107	19 (9 S; 10 W)

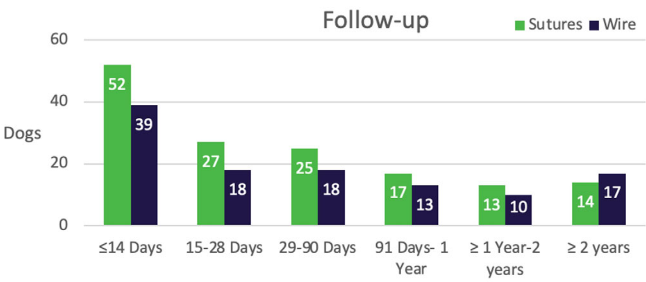

FIGURE 2 Chart illustrating the follow-up per group of closure method

"other" which included pericarditis, pericardial cyst, chylothorax and vena cava perforation.

A total of 37 of 263 (14.1%) dogs experienced postoperative complications related to MS closure. Seventeen dogs experienced complications in the suture group (11.5%) and 20 dogs (17.4%) in the wire group. Twenty-three were mild (12 wire; 11 suture), four moderate (one wire; three suture) and ten severe (seven wire; 3 suture) (Table 3, case details in Tables 4 and 5). The complications were analyzed as a group and not further analyzed based on severity.

Of the 37 dogs, seven (2.7%) had surgical site infection confirmed by culture, four dogs in the wire group and three in the suture group. Surgical site infections were not further classified into subcategories. Bacteria cultured were *Escherichia coli*; Methicillin-Resistant *Staphylococcus pseudointermedius*, *enterococcus faecalis* and Coliform bacteria. Other complications reported included seroma formation ($n = 14$), wound dehiscence ($n = 6$), wound effusion ($n = 3$), postoperative lameness ($n = 3$), sternal fracture ($n = 2$), wire breakage ($n = 1$), perforated internal thoracic artery ($n = 1$), insufficient closure of the soft tissues ($n = 1$), wound edema ($n = 1$), draining sinus tract ($n = 1$) and intermittent pyrexia ($n = 1$). Ten dogs underwent revision surgery, nine due to closure-related complications. Of these nine dogs, one had an exploratory laparotomy for a persistent draining tract of the cranioventral abdomen which originated from the xiphoid region. The other dogs had either a full MS performed where closure of the MS was repeated (two dogs both closed with wires initially, one wire closure was repeated, the other unknown), wires removed (two dogs) or debridement and closure was superficial leaving the original wires or sutures in place (four dogs).

Of 107 dogs followed over 42 days in the study, 19 dogs experienced complications related to the MS closure (17.8%), nine in the suture group (8.4%) and 10 in the wire group (9.3%).

Treatment effects analysis showed a mean of 2.3% lower incidence of complications (listed in Table 3) associated with using suture versus wire, but with the confidence interval (95% CI: −9.1% to +4.5%) including the null value. These results are compatible with the possibility that suture closure was clinically meaningfully superior (since the upper 95% confidence boundary indicated that it might possibly be associated with as much as a 9% reduction in complications over wire closure). In multivariable logistic regression, methods of closure, veterinary center, age, and reason for surgery were not associated with complications but increasing dog weight was (OR = 1.05 [95% CI: 1.01–1.09], $p = .01$). This effect of dog size was not modified by the type of closure used (interaction term: OR = 0.99 [95% CI: 0.96–1.01]).

4 | DISCUSSION

This study did not identify a meaningful difference in complication rates between MS closed with wire or suture and therefore we rejected our hypothesis. Our study suggested that dog weight was associated with risk of closure-related complications regardless of closure-method. It has previously been reported that dogs with short-term complications following MS were heavier[7] and it was proposed that this was due to the ventral location of the incision over a bony prominence.[5,7]

The overall complication rate in this study was 14.1% which is lower than previously reported (17%–78%).[1,4–9] Previous studies have reported multiple complications

TABLE 3 Distribution of mild, moderate, and severe complications and deaths in dogs between weight categories (<20 and ≥20 kg) and MS closure method (wire vs. suture), classified by the Accordion system

	Wire	Suture	Wire	Suture	Wire	Suture	Total (*N*)
Complications	**<20 kg**	**<20 kg**	**≥20 kg**	**≥20 kg**	**All weights**	**All weights**	**All weights and material**
Mild	1/21	2/62	11/94	9/86	12/263	11/263	23/263
Moderate	0/21	2/62	1/194	1/86	1/263	3/263	4/263
Severe	0/21	2/62	7/94	1/86	7/263	3/263	10/263
Death	0/21	0/62	0/94	0/86	0/263	0/263	0/263

following MS including sternal instability, osteomyelitis, pain, incisional edema, skin dehiscence and infection, without necessarily trying to differentiate between complications that were related to the sternotomy closure and complications related to the disease process.[5,7,30] In human medicine, the complication rate associated with MS was reported to be 0.5%–5%, considerably lower than in veterinary medicine.[4,9,10,31] Species and patient diversity and absence of standard agreement of what constitutes a complication in veterinary studies and variation in post-discharge surveillance, may be reasons for this difference.[7,32–34] The confirmed infection rate of 2.7% in this study is within a previously reported rate of surgical site infections in small animal surgery. Weese (2008) reported a median surgical site infection rate of 4.5% (0.8%–18.1%) in orthopedic procedures.[33] By classifying complications in accordance with the Accordion classification reported by Follette et al.,[28] we aimed to categorize complications without bias. By extensive and selective data collection we attempted to focus on complications related to the sternotomy site and closure method and not to the underlying disease process. Unfortunately, sometimes these overlapped. For example, one dog underwent revision surgery due to blockage of a pleural port (Pleuralport Norfolk Vet Products) (Table 5 – case 4). During surgery sternal dehiscence was noted. If the port had not been blocked, revision surgery would not have occurred, and the complication was recorded as moderate.

A previously performed biomechanical study has shown that suture (four metric polydioxanone) could provide as effective closure of the sternum as orthopedic wire (12 gauge) in 12 greyhounds.[15] The same has been shown with the use of crimped nylon leader (40 or 80 lb) in dogs varying 12–38 kg.[14] The estimated risk of developing a closure-related complication, while taking into account other known or potential risk factors, such as dog weight, was equivalent between groups in our study. It therefore supports the conclusion that closure of MS with suture and wire are both suitable options in dogs including those of large (≥20 kg) size. This finding is compatible with a previous in vivo experimental study in which no clinical difference nor difference in complication rate was noted at day 28 post-surgery between dogs with MS closure with wire or suture.[4] Interestingly, this study concluded that wire closure was preferable to suture due the superior sternal healing on histology and the smaller fracture gap.[4] However follow-up time of 28 days is too short to draw firm conclusions regarding sternal healing since none of the sterna showed complete osseus healing. This is confirmed by another study, in which median sternotomies were closed with wire; most of them did not show radiographic signs of osseus healing, or demonstrated only partial healing at 30 days post-surgery.[1]

With our median follow-up of 29 days for the wire group and 26 days for the suture group, and the absence of routine postoperative imaging, we could not make definitive conclusions on sternal healing. Assessing sternal healing was not the objective of this study. A minimal follow-up time of 5 days postoperatively was decided since increasing the time to 14 days (routine time wound assessment post-surgery) and 42 days (routine assessment time of bone healing) would lead to a marked decrease in noted complications (Table 2). By excluding these dogs, complications such as revision surgery (Table 4 – case 10), wound effusion (Table 4 – case 13), seroma (Table 4 – case 14; Table 5 – case 10) and surgical site infection (Table 5 – case 5) would have been missed.

The treatment effect analysis used in this study provided a method to balance out possible differences in allocation to treatment type between individual dogs and to model what the outcomes "might have been'" were the alternative treatment to be given, whilst taking into account various factors (e.g., dog size, age, disease process) that might affect outcome. The focus on effect size is useful because it is more directly clinically relevant than statistical difference. Treatment effect analysis showed a mean of 2.3% reduction in closure-related complications associated with using suture versus wire. The only factor associated with increased risk of closure-related complications was dog size ($p = .01$) and this effect was not modified by the type of closure used. The likelihood of developing a closure-related complication

TABLE 4 Case description of dogs in the wire-group with a complication related to the median sternotomy

					Complication				
Case	Breed	Weight (kg)	Condition	Follow-up (days)	Classification	Surgical site infection	Description	Occurrence days postoperatively	Intervention
1	English springer spaniel	17.4	Pyothorax	29	Mild	No	Seroma formation	4 days	None
2	English springer spaniel	23.1	Pyothorax	75	Mild	No	Seroma	Not mentioned	None
3	Staffordshire bull terrier	24.8	Mass removal	17	Mild	No	Thoracic limb lameness	17 days	None
4	Greyhound	26	Trauma	361	Mild	No	Seroma	10 days	None
5	Boxer	26.2	Mass removal	24	Severe	Yes	Wound dehiscence and infection	16 days	Revision surgery MS – wound debrided and closed. Previously placed wires left in place. Culture performed (*Escherichia coli*; Methicillin-resistant Staphylococcus pseudintermedius)
6	German shepherd dog	27.7	Pneumothorax	462	Mild	No	Surgical site mass noted, suspected wire reaction.	13 months	None
7	Labrador retriever	28.2	Trauma	369	Severe	Yes	Infection	6 months	Revision surgery MS to remove wires – culture performed (*pseudomonas intermedius*)
8	German shorthaired pointer	29	Mass removal	263	Mild	No	Intermittent thoracic limb lameness and pyrexia	During first 2 months	None
9	Labrador retriever	29	Pyothorax	14	Mild	No	Seroma	8 days	None
10	Labrador retriever	29.2	Pyothorax	12	Severe	No	Marked wound effusion	Noted during hospitalization	Revision surgery MS – noted insufficient closure pectorals. Previously placed wires left in place.

TABLE 4 (Continued)

					Complication				
Case	**Breed**	**Weight (kg)**	**Condition**	**Follow-up (days)**	**Classification**	**Surgical site infection**	**Description**	**Occurrence days postoperatively**	**Intervention**
11	German shepherd dog	30	Pneumothorax	131	Severe	No	Sternal fracture	5 weeks	Revision surgery (MS) – wires replaced
12	German shepherd dog	32.2	Pneumothorax	53	Mild	No	Seroma	2 days	None
13	Old English sheepdog	33.4	Pneumothorax	7	Mild	No	Effusion wound	Noted during hospitalization	None
14	Labrador retriever	34.8	Mass removal	13	Mild	No	Seroma	13 days	None
15	Weimaraner	34.8	Mass removal	159	Severe	Yes	Sternal fracture and osteomyelitis.	4 months	Revision surgery (MS). – wires removed. Culture performed (*Pseudomonas intermedius*)
16	Labrador retriever	35.1	Mass removal	33	Severe	No	Hemothorax	Same day of procedure	Revision surgery (MS) – perforated thoracic artery. Closure method revision surgery not mentioned.
17	Cross breed	38.5	Mass removal	925	Mild	No	Seroma	2 days	None
18	Rhodesian ridgeback	42	Pyothorax	19	Mild	No	Seroma	1 day	None
19	Bernese mountain dog	43.3	Pneumothorax	708	Severe	No	Migration wire causing small abscesses	15 months	Revision surgery (MS) – wire removal
20	Great Dane	56	Pneumothorax	17	Moderate	Yes	Surgical site infection	Noted during hospitalization	Cultured, bacterial growth noted (*Staphylococcus aureus*; *Pseudomonas aeruginosa*; *enterococcus faecalis*)

Abbreviation: MS, median sternotomy.

TABLE 5 Detailed case description of dogs in the suture group with a complication related to the median sternotomy

Case	Breed	Weight (kg)	Condition	Follow-up (days)	Complication: Classification	Surgical site infection	Description	Occurrence days postoperatively	Intervention
1	Cocker spaniel	11.7	Pyothorax	35	Severe	No	Wound breakdown	33 days	Revision surgery (MS) to close wound over sternum. Sternotomy sutures left in place.
2	English springer spaniel	11.8	Pyothorax	1150	Severe	Yes	Draining tract formation	6 weeks	Revision surgery (exploratory laparotomy)- culture confirmed bacteria (unknown)
3	Cocker spaniel	13.5	Pyothorax	1520	Mild	No	Seroma and mild dehiscence	11 days	None
4	Cocker spaniel	14.5	Mass removal	41	Moderate	No	Mild sternal dehiscence	23 days	Patient underwent revision surgery but unrelated to sternal dehiscence
5	English springer spaniel	16.7	Pyothorax	11	Moderate	Yes	Surgical wound infection dehiscence	9 days	Coliform bacteria and Klebsiella pneumoniae grown. Antibiotics prescribed
6	Beagle	17.5	Mass removal	25	Mild	No	Wound breakdown	2 days	None
7	English springer spaniel	21	Pyothorax	368	Mild	No	Seroma	Not mentioned	None
8	Labrador retriever	21.9	Mass removal	71	Moderate	Yes	Surgical site infection	Not mentioned	Culture performed (Klebsiella pneumonia) – antibiotics given
9	Cross breed	25.2	Mass removal	16	Mild	No	Seroma	3 days	None
10	German shorthaired pointer	27.1	Pneumothorax	9	Mild	No	Seroma	9 days	None
11	German shepherd dog	31.5	Pneumothorax	249	Mild	No	Oedema surgical site	Not mentioned	None
12	Greyhound	31.6	Pneumothorax	17	Mild	No	Seroma and thoracic limb lameness	17 days	None
13	Labrador	31.7	Pneumothorax	347	Mild	No	Thoracic limb lameness post procedure	14 days	None
14	Golden retriever	34.8	Pneumothorax	62	Mild	No	Serosanguinous discharge	2 days	None

TABLE 5 (Continued)

Case	Breed	Weight (kg)	Condition	Follow-up (days)	Complication				
					Classification	Surgical site infection	Description	Occurrence days postoperatively	Intervention
15	Cross breed	35.2	Mass removal	102	Severe	No	Wound dehiscence	7 days	Revision surgery (MS) – wound debrided and resutured. Initial sternotomy sutures left in place.
16	Labrador retriever	35.5	Mass removal	463	Mild	No	Seroma	4 days	None
17	Husky	38.5	Pneumothorax	33	Mild	No	Serosanguinous discharge	2 days	None

Abbreviation: MS, median sternotomy.

was equivalent between sutures and wires, independent of dog size, despite a higher proportion of complications seen in larger dogs (≥20 kg). The mean difference between suture and wire in this large number of MS cases is not clinically meaningful, suggesting that there is little reason to select one closure material over the other. Nevertheless, the results are also compatible with the possibility that suture closure is clinically meaningfully superior (since the upper 95% confidence boundary indicates that it might possibly be associated with as much as a 9% reduction in complications over wire closure).

This study has several limitations. A major limitation was the decision to include dogs with a minimum of 5 days post-surgery instead of a longer follow-up, which lead to a short median follow-up time, 26 and 29 days for the suture and wire group, respectively. Of the 37 complications noted in our study, seven occurred or were noted after 1 month, and it is therefore possible that complications had not yet occurred and our reported complication rate may have been an underestimation. As a retrospective study, it is possible that some complications might not have been included. Dogs would have been treated differently based on institutions or surgeon's preference regarding choice of closure and/or suture material. Information regarding postoperative coaptation was absent. Surgeon's rationale for the choice of material was listed as surgical preference, or not available. Noteworthy is, that the wire group <20 kg included fewer dogs compared to the other three groups. Another limitation was the relatively low overall rate of complications, which limits the precision of estimation of relative effects. The complications were analyzed as a group and not further analyzed based on severity. Surgical site infection was not further classified and due to the relatively low occurrence (four in wire group and three in suture group) could not be further analyzed. The type of sternotomy (partial vs. complete) was not consistently noted in the medical record and it is possible that intrinsic stability might have been different between groups. It is unknown if a partial sternotomy with preservation of the manubrium and/or xyphoid process or both, once closed, are mechanically stronger than full sternotomies and whether any mechanical differences exist between the types of partial sternotomies. No routine imaging was performed post-surgery, so no conclusions could be made regarding sternotomy site healing and the influence on complications. Finally, even though the methodology used to analyze the data is designed to mitigate for the lack of RCT, it is still a second-best option for determining the answer to this type of clinical question.

Despite these limitations, this study indicated that the incidence of closure-related complications after MS is low compared to other reports.[1,4,5,7,8] In conclusion, the likelihood of developing a closure-related complication was equivalent between sutures and wires, independent of dog size, despite a higher proportion of complications seen in larger dogs (≥20 kg). The lack of a significant interaction between dog weight and type of closure material extends this conclusion to suggest that both closure methods are appropriate for any size of dog.

AUTHOR CONTRIBUTIONS

Mariette A. Pilot: Acquisition, analysis and interpretation of data of institution. Final approval of the completed article. Aaron Lutchman: Acquisition, analysis and interpretation of data. Julie Hennet: Acquisition, analysis and interpretation of data. collected 51 cases of which 44 were included. Davina Anderson: Assisted JH with data acquisition, analysis and interpretation of data. Final approval of the completed article. William Robinson: Acquisition, analysis and interpretation of data. collected 53 cases of which 32 were included. Final approval of the revision manuscript Matteo Rossanese: Acquisition, analysis and interpretation of data. Collected data on 31 cases of which 24 were included. Final approval of the revision manuscript Angelos Chrysopoulos: Acquisition, analysis and interpretation of data of 25 cases of which 20 included to final draft manuscript. final approval of the completed manuscript. Jackie Demetriou: Assisted AC with the acquisition, analysis and interpretation of data. invlved in drafting manuscript Final approval of the revised article Benito De la Puerta: Involved in acquisition, analysis and interpretation of data, collected data on 21 cases, of which 16 made it to final draft manuscript. Involved in drafting of the article and revising it for intellectual content final approval of the completed article Ronan A. Mullins: Involved in acquisition, analysis and interpretation of data, data collected of 13 cases of which nine were included to final draft manuscript. Involved in drafting of the article and revising it for intellectual content final approval of the completed article. Hervé Brissot: Involved in acquisition, analysis and interpretation of data, data collected of nine cases of which seven were included to final draft manuscript. Involved in drafting of the article and revising it for intellectual content final approval of the completed article. Nicholas Jeffery: Statistical analysis of the data (propensity scoring analysis), drafting of the article, revising it for intellectual content, final approval of the completed article Guillaume Chanoit: Conception and design of the study, organizedethical approval for study, analysis of data, drafting of the article, contribution to statistical analysis, revising it for intellectual content, final approval of the completed article. Involved in case collection from institution.

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CONFLICT OF INTEREST

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

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