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Original article

The utility of patent ductus arteriosus closure with hemostatic clip in dogs

A. Takeuchi[1], A. Uemura[2], S. Goya[1], K. Shimada[1], T. Yoshida[1], S. Hara[1], K. Sato[1], K. Shiraishi[1], A. Yairo[1], K. Kto[1], K. Matsuura[1], R. Tanaka[1]

[1] Department of Veterinary Surgery, Faculty of Veterinary Medicine,
Tokyo University of Agriculture and Technology, 3-5-8 Saiwai, Fuchu, Tokyo, 183-8509, Japan
[2] Graduate School of Life and Environmental Sciences,
University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki, 305-8572, Japan

Abstract

This study investigated the utility of patent ductus arteriosus (PDA) closure with hemostatic clip by comparing with traditional PDA closure. Medical records of 51 dogs with surgical closure of PDA were reviewed and retrospective study was conducted. 29 dogs were treated by procedure with hemostatic clip (Group HC), and 22 dogs were treated by surgical ligation (Group SL). Data pertaining to breed, sex, age and body weight at the time of surgery, echocardiographic minimal ductal diameter, duration of surgery, hemostatic clip size, echocardiographic findings, hemorrhage, residual ductal flow and recanalization were collected from records. The results showed that procedure with hemostatic clip had been selected in lighter dogs than traditional PDA closure. Duration of surgery performed only hemostatic clip technique was significantly shorter than that in group SL. Preoperative LVIDd, E-wave and FS were significantly lower than postoperative ones. As regard all parameters, the differences between pre- and postoperative periods were not significantly different between group HC and group SL. Hemorrhage, residual ductal flow, and recanalization were not significantly different in both groups. The present study showed that procedure with hemostatic clip is beneficial in that it is available in smaller dogs and can make shorter operation duration than traditional PDA closure. Moreover, the procedure is effective for the resolution of volume overload of the left atrium and ventricle in short-term outcome. Complications including hemorrhage, residual ductal flow and recanalization were not significantly different with both techniques.

Key words: patent ductus arteriosus, hemostatic clip, transesophageal echocardiography, dog

Correspondence to: R. Tanaka, e-mail: ryo@vet.ne

Table 1. Comparision of parameters between procedure with hemostatic clip (Group HC) and surgical ligation (Group SL).

Parameter	Group HC (n=29)			Group SL (n=22)			P value
Numeric data							
Parameter	N	Mean±SD	Range	N	Mean±SD	Range	
Age (month)	26	5.9±6.9	1-36	21	11.9±13	2-60	0.026
Body weight (kg)	29	1.6±1.0	0.53-5.54	22	2.8±5.54	0.65-8.78	0.0022
MDD (mm)	28	4.0±1.3	2.0±7.8	21	4.5±1.5	2.4-9.2	0.14
Duration of surgery (min)	29	49±19	19-100	18	58.2±27.2	30-130	0.3
Duration of surgery (min)*	17	41.8±19	19-100	18	58.2±27.2	30-130	0.032
Categorical data							
Parameter	N	Number	%	N	Number	%	
Hemorrhage	29	2	0.07	22	3	0.14	0.64
Redisual shunt flow	28	4	0.14	21	8	0.38	0.092
Recanalization	29	1	0.03	22	1	0.05	1

Values of $p \leq 0.05$ were considered significant.
* In 17 dogs excluded 12 dogs changed procedure in intraoperative period in group HC.

Introduction

Patent ductus arteriosus (PDA) is a common congenital heart defect in dogs (Tidholm 1997). PDA typically causes a left-to-right shunt that results in volume overload of the left ventricle and induces congestive heart failure. Without surgical closure of PDA, more than 60% of cases will die within one year from diagnosis (Eyster et al. 1976). PDA closure is considered curative, and it should be done as early as possible after diagnosis. The surgical closure in small puppies shows some difficulty and fatal risk, however, waiting a patient to grow up has also a risk of the development of heart failure. Previous study reported that hemorrhage many occurred in surgeries in older animals (Bureau et al. 2005), therefore, the selection of the surgical procedures and timing for the surgery seems so important for better prognosis.

Although transcatheter embolization is becoming popular in the veterinary field as a safe and efficacious procedure, limited size of the device is sometime problematic for the early stage treatment in puppy dogs with PDA. Coil occlusion generally requires 4 French catheter and ACDO requires at least 5 French depending on the size of devices (Gordon and Miller 2005, Gordon et al. 2010). The puppy dog weighing less than 1 kilogram has some problems in vascular access. In such cases, interventional approach seems difficult so that open chest surgery will be the only choice for the treatment.

Standard dissection technique and Jackson-Henderson method have been reported as surgical ligation procedures. Standard technique requires an approach in the medial aspect of the ductus and sometimes cause unexpected and lethal bleeding. In contrast, Jackson-Henderson method and technique with hemostatic clip can decrease the risk of hemorrhage by avoiding unnecessary medial dissection (Goodrich et al. 2007), however, it carries higher risk of residual ductal flows caused by entrapment of connective tissue on the medial aspect. Technique with use of hemostatic clip also may result in residual ductal flows if depth of resecting connected tissues was not sufficient (Breznock et al. 1971). To overcome the problems of residual flow, transesophageal echocardiography (TEE) is available to detect residual ductal flow, giving the opportunity to apply additional clip or suture to abolish residual ductal flow (Ho et al. 1999).

We have focused on procedure using hemostatic clip that can be accomplished with small chest opening compared with traditional PDA closure, and is expected to contribute to reduced operating time. In the present study, retrospective study was conducted to evaluate the utility of PDA closure with hemostatic clip by comparing with traditional PDA closure. The duration of surgery, the occurrence of hemorrhage and residual shunting and recanalization, and short-term outcome by echocardiographic measurements were used as parameter for the comparison.

Materials and Methods

In the present study, retrospective study was conducted to evaluate usefulness of PDA closure with hemostatic clip by comparing with traditional PDA clo-

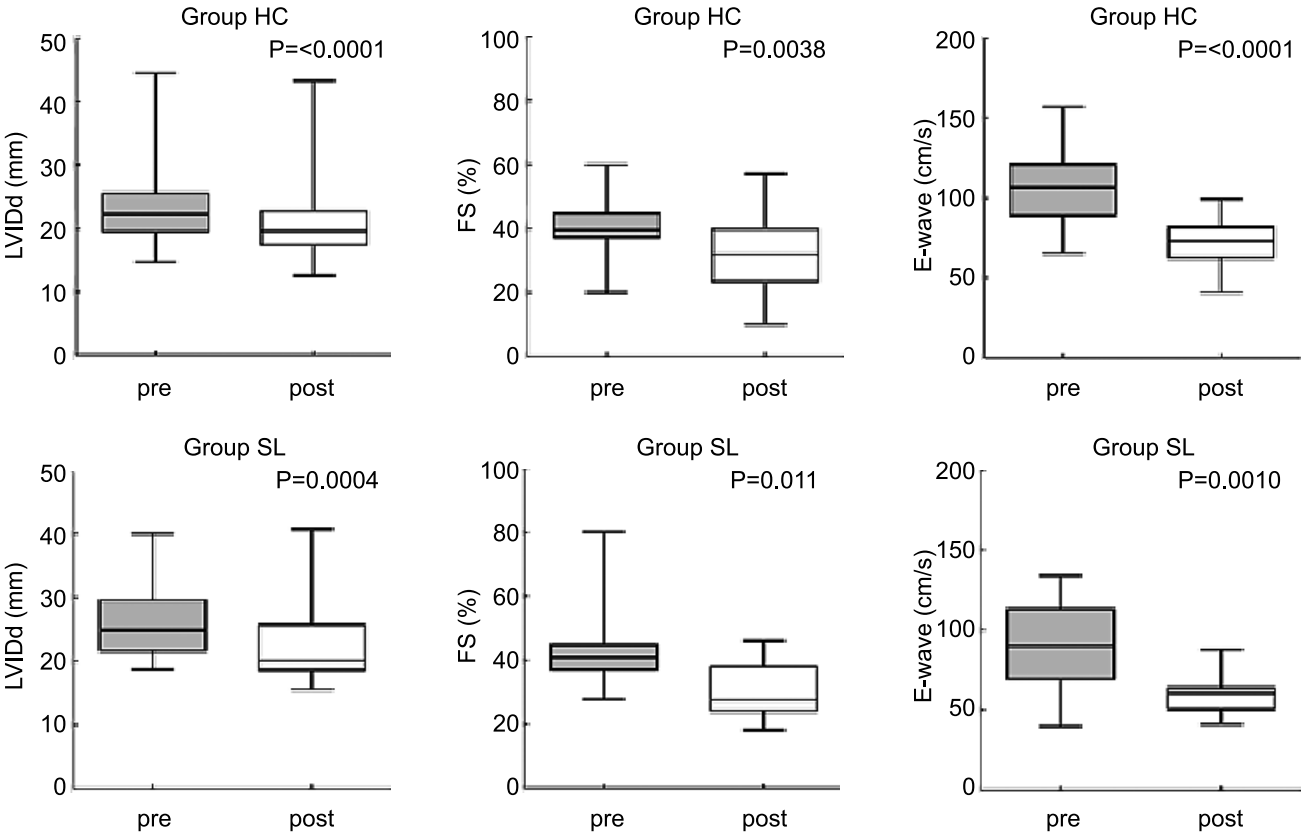

Fig.1. Pre- and postoperative echocardiographic findings.
Preoperative LVIDd, E-wave and FS were significantly lower than postoperative ones in both groups.

sure. Medical records of 51 dogs with surgical closure of PDA at the Tokyo University of Agriculture and Technology Animal Medical Center between 2008 and 2019 were reviewed. 29 dogs were treated by procedure with hemostatic clip (Group HC), and 22 dogs were treated by surgical ligation (Group SL).

Most procedures in both groups were performed by a left fourth intercostal thoracotomy and intrapericardial approach. Standard dissection technique and Jackson-Henderson method in Group SL was performed by ligation with 0 or 1-0 silk suture material. Standard dissection technique was performed by passing ligature directly around the duct. Jackson-Henderson method was performed by passing indirectly. 13 dogs were treated by standard dissection technique and 7 dogs were treated by Jackson-Henderson method. In unknown procedure, 0 silk suture was used in 2 dogs. Procedure with hemostatic clip was performed by application of hemostatic clips (Titanium Ligating Clips, Aesculap, Japan) on the ductus after cranial and caudal dissection of the ductus. Intraoperative TEE was performed in 16 of 29 dogs for HC and performed in 19 of 22 dogs for SL. For TEE, transesophageal electronic sector probe (UST-52119S, Hitachi Aloka Medical, Japan) connected to ultrasound system (ProSound SSD-α10 or ProSound F75 PremierCV, Hitachi, Ltd. Japan) was used.

Data pertaining to breed, sex, age and body weight at the time of surgery, echocardiographic minimal ductal diameter (MDD), duration of surgery (from time of skin incision to placement of the final skin suture), hemostatic clip size, echocardiographic findings, hemorrhage, residual ductal flow and recanalization were collected from records. Pre- and postoperative echocardiographic data recorded included left ventricular internal dimensions in diastole (LVIDd), early diastolic filling velocity (E-wave), fractional shortening (FS).

All statistical analyses were conducted using Prism version 5.0 (GraphPad Software, San Diego, USA). Mann Whitney test was used to compare dog age, body weight, MDD and duration of surgery between groups. Wilcoxon matched-pairs signed-ranks test was used to compare echocardiographic data between pre- and postoperative period. Fisher's exact test was used to compare hemorrhage rate, incidence of residual ductal flow and recanalization rate between groups. Significance was determined at the 5% level and 95% confidence intervals are reported.

Results

For 12 of 29 dogs in group HC, surgical ligation has been first attempted, but it has been changed to proce-

dure with hemostatic clip due to difficulty in surgical approach to the duct. Both groups (n=51) contained Pomeranians (21), mixed-breed dogs (14), Toy poodles (7), Chihuahuas (5), Shetland Sheepdog (1), Papillon (1), Border Collie (1), and Welsh Corgi (1). 23 dogs were female and 28 were male in both groups. The percentage of female dogs was not significantly different between group HC and group SL (p=0.58).

The dogs in the group HC were significantly younger than the dogs in group SL (p=0.026), and half of them were less than 3 months old (Table 1). The dogs in the group HC were significantly lighter than dogs in group SL (p=0.0022) (Table 1), and one third of them were less than 1.0 kg. MDD was not significantly different between groups (p=0.14) (Table 1). Duration of surgery was not significantly different between groups (p=0.30). However, in 17 dogs excluded in 12 dogs changed procedure in intraoperative period in group HC and duration of surgery was significantly shorter than that in group SL (p=0.032) (Table 1). In Group HC, hemostatic clip size (n = 28) was M (3), ML (17), L (7), M and L (1).

3 dogs in Group HC and 5 dogs in Group SL were excluded from statistical analysis because echocardiographic data were unavailable. Preoperative LVIDd, E-wave and FS were significantly lower than postoperative (Fig. 1). As regards all parameters, the differences between pre- and postoperative periods were compared between Group HC and Group SL. All parameters were not significantly different between both groups (p=0.22, p=0.28 and p=0.73, respectively) (Fig. 1).

2 dogs in Group HC and 3 dogs in Group SL (2 dogs in standard dissection technique and 1 dog in Jackson-Henderson method) had intraoperative bleeding during dissection of PDA. One dog in standard dissection technique died due to fatal hemorrhage. Other dogs resolved after placement of the clip or without treatment. Hemorrhage rate was not significantly different between both groups (p=0.64) (Table 1). Residual ductal flow remained in 4 of 28 dogs in Group HC and in 8 of 22 dogs in Group SL (3 dogs in standard dissection technique and 5 dogs in Jackson-Henderson method). One dog in Group HC needed a second procedure to correct residual ductal flow and the coil embolization was successfully performed 5 months later. Residual ductal flow in other dogs was not hemodynamically significant. Incidence of residual ductal flow was not significantly different between both groups (p=0.092) (Table 1). Recanalization occurred because the hemostatic clip came off from the duct in one dog in Group HC. The coil embolization in this dog was successfully performed 6 months later. Recanalization occurred because the ligature probably has become loose in one dog in Group SL. The procedure of ligation and hemostatic clip in this dog was successfully performed 5 months later. Recanalization rate was not significantly different between both groups (p=1.00) (Table 1). In the cases having the second surgery, only data from the original surgery were included in the analyses.

Discussion

The present study investigated the usefulness of hemostatic clip for the PDA closure by comparing with traditional PDA closure. The results showed that procedure with hemostatic clip was likely to be selected in lighter weight dogs than traditional PDA closure techniques, and the use of hemostatic clip can contribute to the reduction of operation time. Hemorrhage rate, incidence of residual ductal flow and recanalization were not significantly different between both groups, whereas postoperative LVIDd, E-wave and FS was significantly reduced in both groups. The breeds of the dogs used in the present study were consistent with the findings in previous studies. On the other hand, a greater proportion of male dogs than female dogs was present in our study (Van Israel et al. 2002, Saunders et al. 2014). Many PDA patient was accepted from the animal breeders, and this will explain this difference, as breeders tend to keep female dogs for the purpose of breeding.

PDA closure should be done as early as possible after diagnosis (Eyster et al. 1976). Recently, advancement of ultrasonography technology has enabled early diagnosis, and opportunities to perform PDA closure in small puppies have been increasing. Limited size devices for transcatheter embolization are becoming problem for very small patients (Gordon and Miller 2005, Gordon et al. 2010), especially for dogs weighing less than 1 kg. In that cases, the open chest surgery will be the only choice. Sometimes PDA closure will cause unexpected and lethal bleeding, as dissecting procedure of the duct is usually sensitive and the approach in the medial aspect of the ductus may cause unavoidable accidents. This difficulty is relevant to all PDA patients, however, especially high in small sized dogs. The present study introduced the hemostatic clip closure of PDA, performed in younger and lighter dogs. Some patients were managed with hemostatic clip because of difficulty in approach to the duct despite that surgical ligation had been first attempted in many small dogs. Procedure with hemostatic clip made possible to perform PDA closure in very small dogs.

The procedure with hemostatic clip was shown to be effective with respect to shorter surgery time (Breznock et al. 1971). On the other hand, another study that found no statistical difference between clip closure

of PDAs and PDA ligation in surgery time (Corti et al. 2000). They reported that the retrospective nature of the study and the small number of evaluated dogs perhaps biassed the evaluation. In addition, skill of the surgeons could also affect the operation time.

The present study showed that duration of surgery was not significantly different between both groups. However, if the dogs, in which the surgical procedure has been changed in intraoperative period were excluded from the group, surgical duration for the hemostatic clip closure will be significantly shorter than that for surgical ligation. The anesthesia can induce cardiovascular collapse more often in the dogs with severe congestive heart failure from PDA. The use of hemostatic clip can make operation time shorter and can reduce risk of perioperative anesthetic complication.

PDA typically causes volume overload of the left atrium and ventricle, resulting in dilatation and eccentric hypertrophy of the left side of the heart. PDA closure is considered curative and results in short- and long-term reverse remodeling in most dogs (Van Israel et al. 2003, Bureau et al. 2005, Hildebrandt et al. 2010). About short-term outcome, we investigated LVIDd, E-wave and FS by echocardiograph for evaluation of cardiac alteration. After surgical treatment, almost all postoperative parameters were significantly decreased in each group. These results showed that procedure with hemostatic clip is also effective in the improvement of hemodynamic status. Major intraoperative complication for PDA closure reported is hemorrhage, and the data about incidence of hemorrhage in open chest closure for PDA is available in some literature (Hunt et al. 2001, Van Israel et al. 2002, Mandhan et al. 2006, Goodrich et al. 2007). In the present study, intraoperative hemorrhage rate was 10% (Group HC 6.9%, Group SL 13%), which was consistent with previous reports on surgical ligation.

In the previous study, procedure with hemostatic clip was reported as being of increased risk of residual ductal flow (Breznock et al. 1971). Another paper also reported that 1 of 20 dogs showed residual ductal flow and the flow diminished on subsequent examinations, however, the result was not compared with other surgical procedures (Corti et al. 2000). In the present study, although not significant, group HC tended to have lower incidence rate of residual ductal flow than group SL. In comparison with surgical ligation, incidence rate of residual ductal flow with hemostatic clip method was not different (Stanley et al. 2003, Saunders et al. 2014). In addition, if follow-up time was longer, spontaneous resolution of residual ductal patency may decrease the incidence rate of residual ductal flow. Furthermore, residual ductal flow in the present study was not clinically significant, except for one dog. The low rate of significant shunt could be attributed to the use of transesophageal echocardiography (TEE). By using TEE, the presence of residual ductal flow can be confirmed in real time and can give the opportunity to apply another clip or suture to stop residual ductal flow (Ho et al. 1999).

Recanalization in humans with various ligation techniques was reported at rate of 1% to 3% (Ghani and Hashim 1989, Yangni-Angate et al. 1995). This recanalization rate is consistent with that in dogs with double ligation of PDA using silk (Birchard et al. 1990). In a study of PDA closure with hemostatic clip in dogs, recanalization reportedly did not occur after the closure (Corti et al. 2000). To the authors' knowledge, the detail of recanalization as a complication after the closure of PDA with the hemostatic clip has yet to be reported. In the present study, the recanalization occurred in one dog in Group HC, and one dog in Group SL. In Group HC, recanalization occurred due to the coming the clip off from the duct, which can be prevented by the use of new type double-shank hemostatic clip (AESCULAP DS Titanium Ligation Clip FC204R, B. Braun).

In summary, the present study showed that procedure with hemostatic clip is beneficial in that it is available in smaller dogs and can make operation shorter than traditional PDA closure. Moreover, the procedure is effective for the resolution of volume overload of the left atrium and ventricle in short term. Complications including hemorrhage, residual ductal flow and recanalization were not significantly different between both techniques. TEE could be effective for reduction of incident rate of clinically significant residual ductal flow.

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