JVC Journal of Veterinary Clinics

Original Article

pISSN 1598-298X • eISSN 2384-0749
J Vet Clin 2022;39:353-359
https://doi.org/10.17555/jvc.2022.39.6.353

Check for updates

Comparison of Continuous Appositional Suture Patterns for Cystotomy Closure in Ex Vivo Swine Model

Sang-hun Park
Joo-Myoung Lee
Hyunjung Park
Jongtae Cheong*

College of Veterinary Medicine, Jeju National University, Jeju 63243, Korea

*Correspondence: cjt123@jejunu.ac.kr

ORCID
Sang-hun Park: https://orcid.org/0000-0002-4135-2112
Joo-Myoung Lee: https://orcid.org/0000-0002-7870-6092
Hyunjung Park: https://orcid.org/0000-0001-8856-5759
Jongtae Cheong: https://orcid.org/0000-0003-4141-718X

Abstract Several suture patterns can be used for cystotomy closure, and a continuous suture pattern is the most commonly used. In this study, the fluid-tight ability and other suitabilities of continuous appositional sutures, such as the simple continuous suture pattern (SC), running suture pattern (RN), and Ford interlocking suture pattern (FI), were compared for cystotomy closure. Cystotomy closure was performed using each suture method in 10 cases of ex vivo swine bladders in each group. Suture time, leakage site, suture length, bursting pressure (BP), bursting volume (BV), and circular bursting wall tension (CBWT) were measured. Suture time and suture length were the shortest in RN and the longest in FI. Leakage occurred in two places: the incision line directly and the hole made by the suture. Leakage occurred through the incision line in 4 bladders of the RN group and 2 bladders of the FI group, but not in the SC group, and in the rest of the bladders, leakage occurred through the suture hole. The values of BP, BV, and CBWT increased in the order of FI, SC, and RN. Suture time and suture length can be considered as factors related to healing and side effects. In this study, leakage through the incision was found in a less appositional area; therefore, leakage through the hole could be considered an indicator of better apposition. Good apposition is one of the conditions required for ideal cystotomy closure. The bursting strength representing the fluid-tight ability can be expressed as the CBWT. RN is expected to be efficient and cause a small degree of foreign body reaction; however, it is expected to be less stable. FI has the greatest fluid-tightness ability, but it has been proposed that side effects due to foreign body reactions most frequently occur in FI. In conclusion, SC, which is expected to have a sufficient degree of fluid-tightness and appropriate recovery, is preferable to other continuous appositional suturing methods for cystotomy closure.

Key words cystotomy, simple continuous suture, running suture, Ford interlocking suture, circular bursting wall tension.

Received November 7, 2022 / Revised December 8, 2022 / Accepted December 28, 2022

Introduction

In veterinary medicine, cystotomy is a frequently performed procedure, and is most commonly indicated in patients with bladder calculi, traumatic bladder rupture, bladder neoplasia, and congenital anomalies such as ectopic ureter (5,18). Failure of cystotomy closure can lead to adhesions, fibrosis, prolonged hospitalization, uroabdomen or peritonitis, which can lead to death in severe case (1,25). Therefore, an ideal suture in cystotomy closure should be completely fluid-tight, easy to apply, cause minimal tension on the incision surface, cause no adhesion formation, maintain the diameter of the bladder lumen, and provide anatomical reapposition between the layers of tissue (23).

When closing the cystotomy, methods for single-layer or double-layer suture patterns using apposition or inverting suture patterns are conventionally suggested (16-18,24). Several studies have argued that single-layer suture patterns are more suitable because they are not significantly different from double-layer suture patterns in terms of the degree of urine leakage and wound strength, but rather provide a shorter running time and healing period and a lower possibility of side effects and tissue damage (12,13,23,25). In addition, in studies comparing the appositional and inverting suturing patterns in the cystotomy closure, no significant difference was found in pressure at the time of leakage between the two suture patterns (2,9,13,23). In previous studies, the single-layer appositional suture pattern did not differ from the double-layer inverting suture pattern in the short-term complication rate and hospitalization period for cystotomy closure in clinical situations (12,25).

The simple continuous suture pattern (SC), running suture pattern (RN), and Ford interlocking suture pattern (FI) are included the continuous appositional suture pattern (15,17). The SC is composed of knots only at both ends of the incision. After making a knot at the starting point, it passes through the tissues perpendicular to the incision from one side to the other. RN is achieved by diagonally advancing along the incision line. In FI, sutures penetrating the tissues are interlocked. In general, it is known that simple continuous suture pattern has better fluid-tight ability than simple interrupted suture pattern, and studies applied to cystotomy closure showed better results (7,17).

To date, no study has compared the continuous appositional suture patterns during cystotomy closure. Therefore, the purpose of this study was to compare continuous appositional suture patterns such as SC, RN and FI.

Materials and Methods

Specimen collection and experiment preparation

Thirty urinary bladders of slaughtered pigs, weighing 100-110 kg and 6 months of age, were removed en bloc from the slaughterhouse. The remaining urine was carefully drained to avoid damaging the mucous membrane of the lumen. The bladders were washed with saline, leaving 3 cm of the urethra and 2 cm of the ureter. After that, the weight of each specimen was measured, ranging between 55-60 g. Each ureter was ligated near the ureter-bladder junction. After inserting the tube through the urethra until the tip was located at the urethra-bladder junction, the urethra was tightened using a cable tie. The tube was connected through a three-way valve to a pressure transducer connected to a pressure monitor (BM7 VET PRO, Bionet, Korea) and an infusion pump (KL-602, Beijing KellyMed Co, China) to inject the solution into the bladder (Fig. 1). A 1% povidone-iodine-saline solution was prepared to check for leakage.

Categorization of the basis of suture pattern

The 30 bladders were randomly categorized into three groups (SC, RN, and FI), with 10 bladders in each group. All bladders were soaked in a heated water bath at 35-36°C for at least 20 min before incision. An incision was made on the ventral surface of the bladder

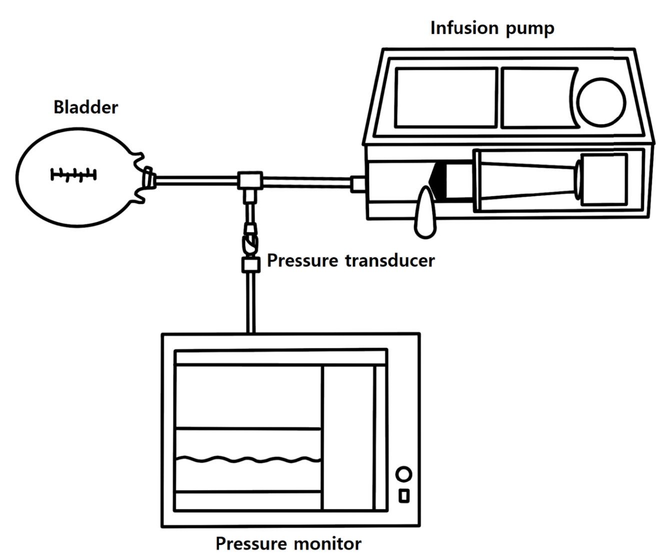

Fig. 1. Apparatuses used to infuse urinary bladders to measure bursting pressure and bursting volume for circular bursting wall tension (CBWT) determinations.

according to the pre-drawn 35 mm lines, and sutures were performed in the manner assigned to each group. The beginning and end of each continuous suture method were completed by making six square knots. For sutures, 3/0 polyglyconate (Maxon™, Covidien™, USA) swaged on a tapered needle was used.

In the SC group, after the first knot, the suture was passed through the bladder serosal surface 5 mm from the edge of the incision line, and then passed through the bladder mucosal surface opposite the incision line on the same vertical level. The interval between sutures was 5 mm. The SC consisted of 14 needle passes through the bladder wall (Fig. 2A).

In the RN group, after the first knot, the route of the first suture passed the wall in the same way as in the SC group, and closure was advanced by 5 mm above the incision. In this way, the suture was placed at the end of the incision, and the suturing was finished with a knot. The RN consisted of 8 needle passes through the bladder wall (Fig. 2B).

In the FI group, the same interval length as that of the SC group was applied, but the incision was closed by applying the Ford interlocking suture patterns in which the sutures were interlocked on the serosal surface. The FI consisted of 14 needle passes through the bladder wall and six interlockings of the suture (Fig. 2C).

The suture time was defined as the time taken from the first pass after the completion of the first knot to the completion of the last knot, and it was measured for all tests. For consistency in each suture trial, one operator performed all sutures.

Evaluation of bladder leakage

After suturing was completed 1% povidone-iodine-saline solution was injected at a rate of 1300 mL/hr using an infusion pump. Then, the bladder lumen pressure and accumulated infusion volume of the solution were measured when leakage of the 1% povidone-iodine-saline solution was observed. The pressure and volume at the time of leakage were called the bursting pressure (BP) and bursting volume (BV), respectively. The leakage site and the suture length used for cystotomy closure by removing the suture were recorded.

Derivation of the circular bursting wall tension

The circular bursting wall tension (CBWT) expressing the bursting strength was derived from the BP and BV measured for all tests. Assuming that the bladder was a sphere, the radius at the time of rupture could be calculated from the BV using the following formula:

$$BV = \frac{4}{3}\pi r^3$$

$$r = \sqrt[3]{\frac{3BV}{4\pi}}$$

BV = bursting volume (mL), r = radius of the sphere when rupture occurs (cm).

CBWT was calculated by applying Laplace's law, which defines the relationship between pressure and wall tension in hollow organs (11,20,23). The formula for deriving the CBWT is as follows:

$$CBWT = \frac{BP \times r \times 1.33 \times 10^3}{2}$$

CBWT = circular bursting wall tension (dyne/cm), BP = bursting pressure (mmHg), r = radius of the sphere (cm), 1 mmHg = 1.33 dyne/cm.

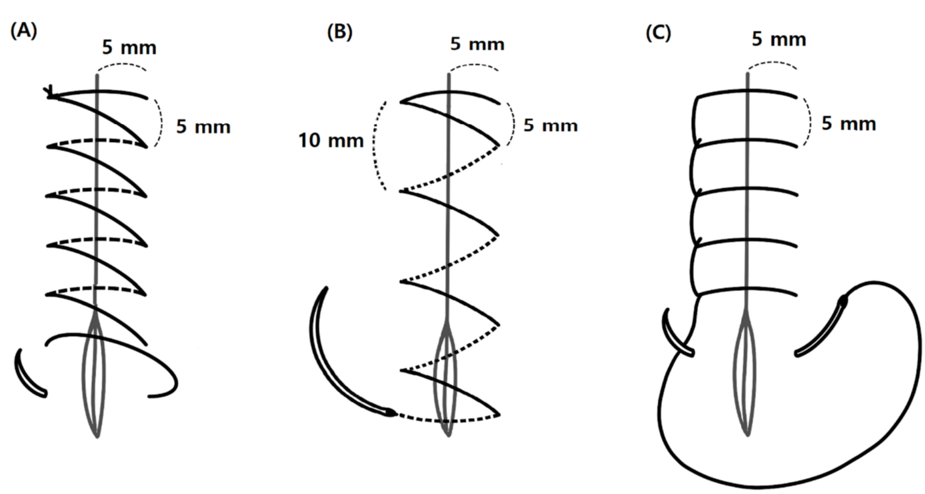

Fig. 2. Each suture pattern used in the experiment. (A) Simple continuous suture pattern. (B) Running suture pattern. (C) Ford interlocking suture pattern.

Statistical analysis

To statistically analyze of the results, the mean values and the standard deviations (SD) were calculated. All experimental results were expressed as mean ± SD and were presented in tables and figures. The three groups were compared statistically with a one-way analysis of variance (ANOVA) using GraphPad Prism software (GraphPad Software, USA). For all tests, $p < 0.05$ was considered to be statistically significant.

Results

Bladder weight, suture time and suture length

The weight of the bladder did not differ significantly ($p > 0.05$) between the three groups (mean ± SD, 59.0 ± 1.48 g, 58.2 ± 1.54 g, 59.0 ± 1.48 g for SC, RN and FI, respectively). The mean ± SD of suture times were 349.9 ± 74.00 sec, 215.9 ± 28.29 sec, and 465.6 ± 84.47 sec in SC, RN and FI groups, respectively. The length of the suture for RN was the shortest, followed by SC and FI in that order (mean ± SD , 60.8 ± 7.47 mm, 40.5 ± 2.73 mm, 91.2 ± 13.12 mm for SC, RN and FI, respectively). The length of suture and the suture time were significantly different ($p < 0.05$) between the groups (Table 1).

Sites of leakage

No suture breakage or untying occurred in the bladder. In this study, leakage of the bladder was observed at two sites: leakage through the incision line directly and the suture hole made by penetration of the suture. In the SC, no leakage occurred at the incision line. In FI, 2 of the 10 bladders showed leakage in the incision line, and in RN, 4 of the 10 bladders showed leakage (Table 2). The remaining bladders in the RN and FI groups showed leakage through the suture hole. The leakage at the incision line in the FI group occurred in the wrinkled areas between the incision edges.

Bursting pressure (BP) and bursting volume (BV)

The mean ± SD of BP were 3.9 ± 0.83, 2.9 ± 0.83, and 5.1 ± 1.22 mmHg in SC, RN and FI groups, respectively. A statistically significant difference was observed between SC and FI groups and between RN and FI groups. However, there was no significant difference between the SC and RN groups (Fig. 3).

The mean ± SD of BV were 349.9 ± 68.58 mL, 234.9 ± 61.73 mL, and 402.7 ± 119.09 mL in SC, RN, and FI groups, respectively. A statistically significant difference was observed between the SC and RN groups and between RN and FI groups. However, there was no significant difference between the SC and FI groups (Fig. 3). From the result, we observed that as BP increased, BV showed a proportional increase too.

Circular bursting wall tension (CBWT)

The mean ± SD of CBWT in the SC, RN, and FI groups were 11206 ± 2229.6, 7284 ± 2041.3, and 15489 ± 4399.0 dyne/cm, respectively (Fig. 3). Statistically significant differences were observed in CBWT among all groups. RN showed the weakest tension, while FI showed the strongest tension among the groups.

Discussion

In many studies, delayed operating and anesthesia times were associated with adverse effects, such as infection (3,4,6). Therefore, several studies comparing cystotomy closure methods have suggested that shorter operation time is a positive factor (7,12,13,20). As the result of this study, it is expected to further contribute to shortening the operation time in the following order: RN, SC, and FI. Thus, the risk associated with adverse effects such as infection was also thought to be lower in the order of RN, SC and FI.

The suture material at the incision line can act as a foreign body, which can delay healing and contribute to infection (26). In addition, the presence of a foreign body in the ab-

Table 2. The leakage site in SC, RN, and FI groups

Leakage site	Group SC (n = 10)	Group RN (n = 10)	Group FI (n = 10)
Incision line	0	4	2
Suture hole	10	6	8

SC, simple continuous suture pattern; RN, running suture pattern; FI, Ford interlocking suture pattern.

Table 1. The weight of the bladder, the suture time, and the suture length for SC, RN, and FI group (Mean ± SD)

Parameters	Group SC (n = 10)	Group RN (n = 10)	Group FI (n = 10)	p value
Bladder weight (g)	59.0 ± 1.48	58.2 ± 1.54	59.0 ± 1.48	> 0.05
Suture time (sec)	349.9 ± 74.00	215.9 ± 28.29	465 ± 84.47	< 0.05
Suture length (mm)	60.8 ± 7.47	40.5 ± 2.73	91.2 ± 13.12	< 0.05

SC, simple continuous suture pattern; RN, running suture pattern; FI, Ford interlocking suture pattern.

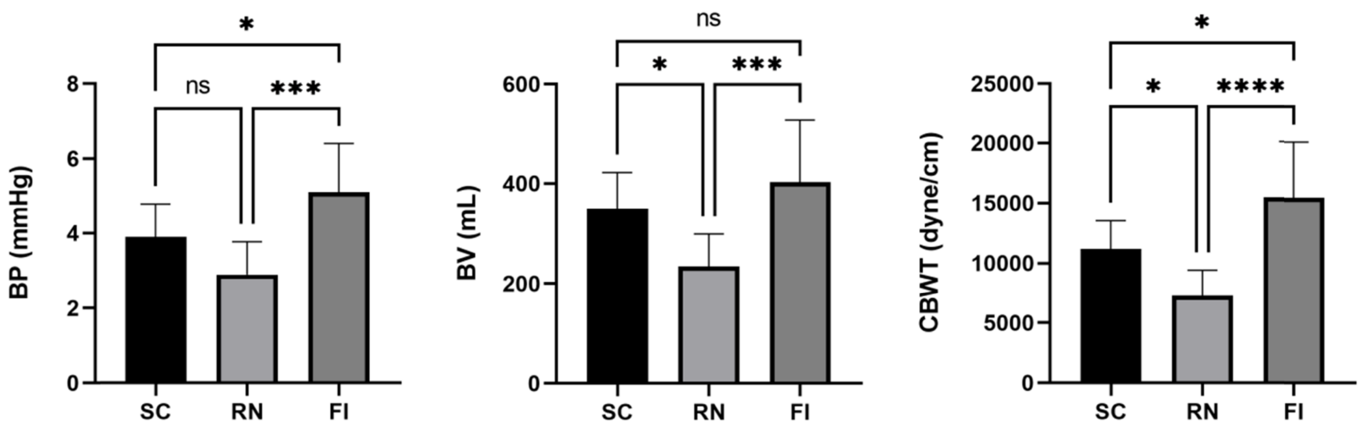

Fig. 3. BV, BP, and CBWT measurement in SC, RN and FI groups. SC, simple continuous suture pattern; RN, running suture pattern; FI, Ford interlocking suture pattern; BP, bursting pressure; BV, bursting volume; CBWT, circular bursting wall tension; ns, not significant. *$p<0.05$, ***$p<0.001$, ****$p<0.0001$.

dominal cavity is one of the most common reasons for adhesions (8,22). The larger the suture volume exposed to the abdominal cavity, the more severe the adhesion (8,14,22). Adhesion of the bladder to the body wall or organs in the abdominal cavity after cystotomy can interfere with normal bladder filling or emptying (22). Therefore, a smaller amount of suture material used is thought to have better results with respect to recovery. From the results of this study, it can be inferred that the most severe foreign body reaction in the closure occurs when FI is applied in clinical practice because the longest length of the suture is used in FI. In addition, because of the largest amount of suture made by the interlocked sutures on the serosal surface of the bladder in FI, intraperitoneal adhesion is thought to be the most severe.

In the RN, leakage occurred at the incision line in 40% of the bladders. It can be suggested that this result was due to the instability of the incision line caused by the long gap between the sutures and the tension acting on the suture while pulling to tighten the suture, causing the bladder surface to move parallel to the incision line. In FI, leakage occurred at the incision line in 20% of bladders. The reason for this result, even with the same distance between sutures as the SC, was probably the wrinkles at the edges of the incisions. These wrinkles were formed because, the interlocking part applied a force to the serosa in the vertical (seroso-mucosal) direction as the suture progressed. As a result, the edge of the incision where interlocking existed was relatively deep compared to the opposite edge. When tension is applied, the RN and FI are thought to have a relatively smaller degree of apposition compared to the SC that is thought to have a relatively better apposition at the suture sites. According to previous studies, the most common leakage site for appositional sutures in the cadaveric bladder was the suture hole (20,23). However, in clinical situations, cystotomy leakage at the suture hole is rare (20). In this experiment, all bladder leakages occurred through the suture hole in SC. The suture hole was also the most common leakage site in RN and FI. Therefore, it is thought that the possibility of urinary leakage in the bladder is further reduced if appropriate apposition is achieved in which leakage does not occur at the incision line during bladder occlusion in vivo.

Bursting strength refers to the resistance to an increase in intraluminal pressure, and it can be expressed as either BP or CBWT (11,23). CBWT is considered to represent the bursting strength more accurately because it takes into consideration the size and shape of the lumen (11,19,23). Therefore, the CBWT results obtained in this study were considered more accurate than the results of simply measuring only BP and BV.

In this study, by comparing the values of CBWT, it was found that FI had better fluid-tight ability than the other suture patterns in terms of mechanical aspects. In the FI suture, the connection between the sutures was made once more on the serosal surface, and the greater tension caused by the use of longer sutures on the incision line caused the strongest CBWT. However, in the RN, the lowest tension on the incision line due to the wide interval between sutures and the use of fewer sutures was thought to be the cause of the lowest CBWT.

The epithelium and connective tissues in the in vivo bladder stretch to accommodate urine and maintain low pressure, as the bladder tension increases, and histological reorganization of smooth muscle cells occurs (10,21). In this experiment, such changes were not observed in the ex vivo bladder, even though the fluid injection rate was much faster than the in vivo urine output. Thus, BP and BV values are thought to become larger in clinical situations than in cadaveric situations. Accordingly, it is thought that CBWT values also increase.

Because this experiment was conducted ex vivo, evaluation of the differences in postoperative healing was not possible according to the suture patterns. In addition, evaluating the effect of physiological responses, such as inflammation, on fluid-tight ability after surgery was not possible. These points are considered limitations of experiments performed ex vivo, and additional studies in vivo may help to evaluate aspects that could not be evaluated in this study.

The fluid-tight ability of the FI was superior to that of the SC in the mechanical aspect. However, FI does not seem suitable for cystotomy closure because of the high possibility of side effects due to foreign body reactions in vivo, the low efficiency of suturing and the difficulty of suturing. Although RN sutures are relatively efficient and easy to suture, their apposition and fluid-tight abilities were poor. Thus, if RN is to be used for cystotomy closure, it should be performed with a suture interval smaller than 5 mm, or a urinary catheter should be used after cystotomy to reduce the inner pressure of the bladder during the initial recovery phase. Therefore, SC is considered preferable to RN and FI for cystotomy closure because of its adequate fluid-tight ability, good apposition, and appropriate efficiency.

Acknowledgements

This work was supported by the 2022 education, research and student guidance grant funded by Jeju National University.

Conflicts of Interest

The authors have no conflicting interests.

References

1. Adams H, Barnes R, Small C, Hadley H. Sutures and bladder wound healing in the experimental animal. Invest Urol 1975; 12: 267-268.
2. Al-Asadi RN, Khwaf NB. A comparative study between inverting and appositional suture patterns for cystotomy closure in dog. Iraqi J Vet Med 2014; 38: 40-47.
3. Brown DC, Conzemius MG, Shofer F, Swann H. Epidemiologic evaluation of postoperative wound infections in dogs and cats. J Am Vet Med Assoc 1997; 210: 1302-1306.
4. Burrow R, Batchelor D, Cripps P. Complications observed during and after ovariohysterectomy of 142 bitches at a veterinary teaching hospital. Vet Rec 2005; 157: 829-833.
5. Cornell KK. Cystotomy, partial cystectomy, and tube cystostomy. Clin Tech Small Anim Pract 2000; 15: 11-16.
6. Cruse PJ, Foord R. The epidemiology of wound infection. A 10-year prospective study of 62,939 wounds. Surg Clin North Am 1980; 60: 27-40.
7. Gözen AS, Arslan M, Schulze M, Rassweiler J. Comparison of laparoscopic closure of the bladder with barbed polyglyconate versus polyglactin suture material in the pig bladder model: an experimental in vitro study. J Endourol 2012; 26: 732-736.
8. Henderson RA. Controlling peritoneal adhesions. Vet Surg 1982; 11: 30-33.
9. Hildreth BE 3rd, Ellison GW, Roberts JF, Adin CA, Holloway TJ, Archer LL, et al. Biomechanical and histologic comparison of single-layer continuous Cushing and simple continuous appositional cystotomy closure by use of poliglecaprone 25 in rats with experimentally induced inflammation of the urinary bladder. Am J Vet Res 2006; 67: 686-692.
10. Hill WG. Control of urinary drainage and voiding. Clin J Am Soc Nephrol 2015; 10: 480-492.
11. Jiborn H, Ahonen J, Zederfeldt B. Healing of experimental colonic anastomoses. I. Bursting strength of the colon after left colon resection and anastomosis. Am J Surg 1978; 136: 587-594.
12. Khan IU, Khan MA, Chaudhary AS, Ali MM, Imran M, Ijaz M, et al. Evaluation of different suturing techniques for cystotomy closure in canines. JAPS 2013; 23: 981-985.
13. Kieves NR, Krebs AI. Comparison of leak pressures for single-layer simple continuous suture pattern for cystotomy closure using barbed and monofilament suture material in an ex vivo canine model. Vet Surg 2017; 46: 412-416.
14. Kirby BM. Peritoneum and retroperitoneum. In: Johnston SA, Tobias KM, editors. Veterinary surgery: small animal expert consult. 2nd ed. Philadelphia: Elsevier Health Sciences. 2017: 1608-1610.
15. Knecht CD, Allen AR, Williams DJ, Johnson JH. Suture patterns. In: Knecht CD, Allen AR, Williams DJ, Johnson JH, editors. Fundamental techniques in veterinary surgery. 2nd ed. Philadelphia: Saunders. 1981: 52-68.
16. Lipscomb VJ. Bladder. In: Johnston SA, Tobias KM, editors. Veterinary surgery: small animal expert consult. 2nd ed. Philadelphia: Elsevier Health Sciences. 2017: 2220-2225.
17. MacPhail C, Fossum TW. Biomaterial, suturing and hemostasis. In: Fossum TW, editor. Small animal surgery. 5th ed. Philadelphia: Elsevier, Inc. 2019: 68-70.
18. McLoughlin M, Scansen B. The urinary tract. In: Williams JM, Niles JD, editors. BSAVA manual of canine and feline abdominal surgery. 2nd ed. Gloucester: British Small Animal Veterinary Association. 2015: 269-271.
19. Nelsen TS, Anders CJ. Dynamic aspects of small intestinal rupture with special consideration of anastomotic strength. Arch Surg 1966; 93: 309-314.

20. Petty RE, Johnston W, McCormick AQ, Hunt DW, Rootman J, Rollins DF. Uveitis and arthritis induced by adjuvant: clinical, immunologic and histologic characteristics. J Rheumatol 1989; 16: 499-505.
21. Phé V, Chartier-Kastler E, Soler JM, Denys P. Pathophysiology of the low-compliant bladder. In: Ginsberg D, Karsenty G, Corcos J, editors. Textbook of the neurogenic bladder. 3rd ed. Florida: CRC Press. 2015: 125-132.
22. Radasch RM. An evaluation of appositional versus inverting suture patterns for cystotomy closure. Ames: Iowa State University; 1988. [thesis].
23. Radasch RM, Merkley DF, Wilson JW, Barstad RD. Cystotomy closure. A comparison of the strength of appositional and inverting suture patterns. Vet Surg 1990; 19: 283-288.
24. Stone EA, Kyles AF. Cystotomy and partial cystectomy. Bojrab MJ, Waldron DR, Toombs JP, editors. Current techniques in small animal surgery. 5th ed. Wyoming: Tenton NewMedia. 2014: 481-482.
25. Thieman-Mankin KM, Ellison GW, Jeyapaul CJ, Glotfelty-Ortiz CS. Comparison of short-term complication rates between dogs and cats undergoing appositional single-layer or inverting double-layer cystotomy closure: 144 cases (1993-2010). J Am Vet Med Assoc 2012; 240: 65-68.
26. Willard MD, Schulz KS, Fossum TW. Surgical infections and antibiotic selection. In: Fossum TW, editor. Small animal surgery. 5th ed. Philadelphia: Elsevier, Inc. 2019: 79-89.