Suturing with or without surgical glue is superior to surgical glue alone for sealing ex vivo swine gallbladders

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OBJECTIVE
To assess the effectiveness of various sealing techniques in cholecystotomies under maximum intraluminal pressure stress using an ex vivo swine model.

SAMPLE
30 gallbladders from different animals were used.

METHODS
The experiment was conducted ex vivo, with the formation of 3 groups, each comprising 10 samples. Group 1 utilized a traditional single-layer Cushing suture made from polydioxanone material. Group 2 employed a single layer of Cushing suture, also made from polydioxanone material, but in conjunction with surgical glue (n-butyl cyanoacrylate). Group 3 relied solely on the use of surgical glue (n-butyl cyanoacrylate) for sealing the edges of the surgical wound. The intraluminal pressure was gauged with a pressure transducer.

RESULTS
The maximum intraluminal pressures (mean ± SD) sustained in G1, G2, and G3 were, respectively, 48.70 ± 21.32 mm Hg, 110.90 ± 37.52 mm Hg, and 10.9 ± 4.07 mm Hg. Comparisons between groups showed that G2 supported significantly higher pressures (56.1% higher) than G1 (P < .001) and G3 (90.2% higher; P < .001). When G1 was compared with G3, a significantly higher pressure (77.6%) was also observed (P < .01).

CLINICAL RELEVANCE
The study’s conclusions demonstrated the safest suture techniques for the gallbladder and provided advice regarding the use of surgical glue.

Keywords: cholecystotomies, cyanoacrylate, gallbladders, surgical glue, swine

Diseases of the gallbladder and extrahepatic biliary tract, while less recognized in veterinary medicine compared to human medicine, also affect dogs and cats. The probable reason these disorders are often overlooked is the lack of knowledge about the signs of biliary tract disease, which can be confused with other disorders owing to their similar clinical signs.1

Cholecystotomy may be performed to obtain a full-thickness biopsy or mucosal cultures of the gallbladder, to explore the gallbladder and cystic duct interior, and to remove choleliths and sludge, when there is no severe inflammatory alteration of the gallbladder wall. It can also be performed for antegrade flushing and assessment of patency of the extrahepatic biliary ducts.2

Cholecystectomy is the most frequently conducted gallbladder surgery in small animals, preferred over cholecystotomy owing to its reduced risk of gallstone recurrence.3,4

Cholecystectomy can lead to adverse physiological effects. These include postoperative abdominal pain and diarrhea, which are often associated with fat malabsorption. Such effects are described in humans and induced in normal dogs and cats undergoing cholecystectomy.5,6

In human medicine, hemostatic agents and tissue sealants are playing an increasingly significant role in the management of trauma and iatrogenic urological injuries. They are utilized either in conjunction with primary surgical therapy or for the prevention of complications.7

Cyanoacrylates, a category of synthetic adhesives, were initially developed by the North American firm Eastman Kodak during the Second World War.7 Despite their frequent application in diverse surgical pro-
cedures, the existing information primarily stems from case reports. Even though these reports often highlight positive outcomes, there is a noticeable absence of standardized guidelines on their appropriate usage. In the context of biliary tract surgeries, literature detailing the use of cyanoacrylates is scarce, and the majority of available resources are also case reports.

Therefore, the objective of this study was to conduct an ex vivo evaluation of the efficacy of various sealing techniques in cholecystotomies, specifically in their ability to withstand maximum intraluminal pressure (MIP) stress using swine gallbladder.

Methods

Ethical aspects
The study was registered under protocol number 001/2022 and submitted to the University of Cuiabá’s (UNIC) Ethics Commission on Animal Use.

Pilot study
A pilot study was conducted to refine the techniques of collection, preparation, dissection, and cholecystotomy, as well as cholecystorrhaphy with and without glue, for application in the current research.

Material collection
The experiment was conducted ex vivo. Gallbladders were sourced from swine slaughtered at a commercial slaughterhouse. Immediately after collection, the vesicles were drained, rinsed with distilled water, and refrigerated at 5 °C for no longer than 8 hours prior to the study. The vesicles were carefully extracted from the livers to preserve the adjacent structures. These were obtained from homogeneous lots of pigs, each with an average weight of 120 kg.

Experimental design
Three groups were established for cholecystotomies, each consisting of 10 samples (n = 10), to evaluate various vesical-sealing methods. These methods involved a 2.0-cm incision in the body of the vesicles. Group 1 (G1) employed a traditional suture technique, utilizing a single layer of Cushing suture with a 4-0 absorbable monofilament suture made of polydioxanone material, cylindrical needle, 2.6 cm, 1/2 circle. Group 2 (G2) used the same suture technique as G1 but in conjunction with surgical glue (n-butyl cyanoacrylate). Group 3 (G3) solely relied on the surgical glue (n-butyl cyanoacrylate) for sealing the edges of the surgical wound.

All gallbladders were macroscopically evaluated by 2 evaluators in a descriptive manner. The whole experiment was performed by the same surgeon, following the literature recommendations.

A multiparameter monitor, equipped with an external pressure transducer and valved tap, was used to measure the MIP of each gallbladder. The transducer was positioned at the same height as the gallbladder for accurate readings.

Two urethral probes, No. 4, were positioned at the level of the gallbladder neck and secured by means of a modified Sultan suture with a 4-0 nylon thread, ensuring no leakage around the probes. A 0.9% saline solution was administered through one of the probes via an infusion pump at a rate of 999 mL/h, while the pressure transducer was connected to the second probe. The pressure sustained by the organ until the point of fluid leakage was identified as the MIP.

Liquid leakage was macroscopically assessed with a qualitative filter paper placed over the incision. This method confirmed the precise moment of leakage as the paper absorbed the liquid. Two evaluators independently conducted the measurement of pressure and liquid leakage. This approach ensured that the monitor was not within the surgeon’s visual field and that one evaluator’s assessment of liquid leakage did not influence the other’s.

Statistical analysis
A completely randomized design was employed, incorporating 3 treatment groups with 10 repetitions each. The data were analyzed with R software, version 4.3.14 (The R Foundation), specifically utilizing the Agricolae, Ggplot2, and ExpDes.pt packages.

Data exhibited homogeneity (P = .75; Bartlett test) and followed a normal distribution (P = .29; Shapiro-Wilk test). Therefore, possible differences between groups were assessed by 1-way analysis of variance, followed by the Tukey multiple comparison test. Differences were considered statistically significant at P < .05.

Results

The MIPs (mean ± SD) sustained in G1, G2, and G3 were, respectively, 48.70 ± 21.32 mm Hg, 110.90 ± 37.52 mm Hg, and 10.9 ± 4.07 mm Hg (Figure 1).

Figure 1—Mean and SDs of maximal intraluminal pressures assessed in ex vivo swine gallbladders sealed using 3 techniques (G1 [suture alone], G2 [suture plus glue], and G3 [glue alone]). Lines above the bars indicate significant differences between groups.
Comparisons between groups showed that G2 supported significantly higher pressures (56.1% higher) than G1 ($P < .001$) and G3 (90.2% higher; $P < .001$). When G1 was compared with G3, a significantly higher pressure (77.6%) was also observed ($P < .01$).

The macroscopic evaluation (Figure 2) was realized in all gallbladders and was similar within each group. In G1, it was observed tissue invagination extending along the surgical suture, consistent with the type of suture employed. This same pattern, with a deeper invagination and edges filled with glue, was noted in G2. Group 3 exhibited a juxtaposition of both surgical wound edges, accompanied by noticeable shrinkage.

![Figure 2—Swine gallbladder. A—G1 (suture alone), a regular Cushing suture with invagination and without macroscopic alteration. B—G2 (suture plus glue), a deeper invagination filled with blue glue. C—G3 (glue alone), a juxtaposition of both tissue edges with a noticeable shrinkage.](image)

**Discussion**

The complexities involved in cholecystotomies and cholecystectomy, coupled with the limited research on the application of cyanoacrylates in gallbladders, motivated us to develop this study. This investigation involved the use of surgical glue, either independently or in conjunction with traditional techniques.

The structure of the gallbladder and major ducts of the biliary system is similar in all species, except for a few species that lack this organ. In this study, the population target was small companion animals like cats and dogs. However, several factors, such as sample homogeneity and the similarity with the swine gallbladder, led to the selection of this species for experimental design.

In swine, the average basal intraluminal pressure of the gallbladders has been reported to be 15 mm Hg. When considering the averages of the study groups, it can be asserted that both the traditional suture (G1) and the combination with surgical glue (G2) supported pressures exceeding the basal, thereby qualifying as safe closure methods. Moreover, G2 demonstrated superior efficiency among the tested groups, thereby presenting itself as an alternative to bolster tissue closure. However, the group that solely utilized surgical glue (G3) withstood an average pressure lower than the basal pressure, indicating potential failure.

The study results showed that the traditional suture (G1) is resistant, and the addition of surgical glue (G2) could be an alternative to increase its resistance when guidelines for cholecystotomy are followed. However, the cholecystectomy remains the standard of care for the treatment of cholelithiasis and gallbladder mucoceles in small animals.

Numerous studies across various tissues and species have explored the use of cyanoacrylates in experimental surgeries. These studies have demonstrated a positive impact on healing and inflammation, suggesting potential advantages over standard treatments, and thus deeming their application feasible. Conversely, a significant body of research also indicates potential detrimental effects of surgical glue on healing and surgical recovery, leading to its contraindication. Although the primary focus of the present study was to evaluate the dynamics of intraluminal pressure in the sealing, macroscopic differences were noted between the 3 groups. Further in vivo research is warranted to evaluate the anatomicopathological shifts in these treatments.

Despite the surgical glue used in this study lacking manufacturer indications for internal procedures, numerous cyanoacrylate formulations have been documented in the literature for use in abdominal cavity surgeries. Consequently, the findings of this study enhance our comprehension of this material’s behavior in cavity organs.

An infusion pump was utilized to perform liquid infusion at a rate of 999 mL/h. This ensured a consistent filling speed of the vesicle contents across all samples, thereby preventing any influence on pressure variation, as previously described by another author. The current study has several caveats. First is the use of a nonphysiological assay method and de-vitalized tissue, which may exhibit different behavior compared to living tissue. Second, the gallbladders were from healthy swine and free of gallbladder pathology, and they may not represent clinical cases. Therefore, further studies should be conducted that use living models to assess sealing performance in terms of tissue resistance to acting forces and healing potential. Finally, it was impossible to standardize and measure the amount of surgical glue applied over the incisions.

In conclusion, the study substantiated that both the traditional suture method (G1) and the combination of suture with glue (G2) in cholecystotomies yielded satisfactory outcomes in terms of pressure resistance. Moreover, the combination of traditional suture and glue (G2) may serve as an alternative reinforcement for tissue closure. However, the group that solely utilized glue (G3) demonstrated an unsatisfactory performance when it was used as the exclusive closure method.

**Acknowledgments**

We thank the slaughterhouse, Forteza, for donating the samples used in the study.

**Disclosures**

The authors have nothing to disclose. No AI-assisted technologies were used in the generation of this manuscript.


