Effect of Electrolyzed Strong Acid Water on Peritoneal Irrigation of Experimental Perforated Peritonitis

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Abstract

Purpose. Electrolyzed strong acid water (ESAW) is generated by the electrolysis of a weak sodium chloride solution. Although ESAW is known to have a strong bactericidal activity and to be harmless to the living body, its effectiveness and safety in the treatment of perforated peritonitis has not been well established.

Methods. Male Wistar rats were used for the study. Three hours after cecal ligation and puncture, the cecum was resected and the peritoneal cavity was irrigated with 50 ml of saline (Group S, n=12) or ESAW (Group E, n=14). The 5-day survival rate was compared between the two groups. In another pair of animals (n=10 each), bacteria in the ascitic fluid were counted at 6 and 18 h after irrigation.

Results. No adverse effects of ESAW were observed in the experimental group. The 5-day survival rate was 25% (3/12) and 85.7% (12/14) in Groups S and E, respectively (P<0.01). The bacterial count at 18 h after the irrigation in Groups S and E was (5.0±2.5)×10⁵/ml and (2.2±2.0)×10⁴/ml, respectively (P<0.0001).

Conclusion. Peritoneal lavage with ESAW had no adverse effect, and achieved more effective decontamination than saline for perforated peritonitis. Therefore, the results of this study are considered to warrant and support the clinical application of ESAW.

Key words Perforated peritonitis · Peritoneal lavage · Electrolyzed strong acid water · Hypochlorous acid water · Bactericidal activity

Introduction

Electrolyzed strong acid water (ESAW) is generated by the electrolysis of a weak sodium chloride solution (20 mM NaCl). Its physiological and chemical characteristics include a pH of 2.7, an oxidative-reduction potential of 1000–1100 mV, a dissolved oxygen concentration of 10–30 ppm, and a chlorine concentration of 30–40 ppm, or 1.2 mM as hypochlorous acid, which has strong bactericidal activity and disinfection potential against viruses. The feasibility and safety of ESAW irrigation in wound infection or ocular surface disinfection have been confirmed in animal models. However, few applications of body cavity lavage with ESAW in clinical cases have been reported in the literature. In order to establish its safety and effectiveness for peritoneal irrigation in perforated peritonitis, an experimental study was conducted.

Materials and Methods

Subjects

Wistar male rats (Nihon Clea, Tokyo, Japan) 7 weeks of age, weighing about 250 g, which were raised preliminarily on a compound feed (Nihon Aqua, Kyoto, Japan), were used for the study. The animals were randomly divided into two groups (14 rats in each group). Two animals in Group S were lost accidentally.

Preparation of Peritonitis

After fasting for 12 h, the animals were anesthetized with pentobarbital, and after disinfecting the abdomen with povidone iodine, a 2-cm midline laparotomy was performed. Perforated peritonitis was made as described by Wichterman et al.: the cecum was ligated just below the ileocecal valve with 3-0 silk without dissection of the
ileocolic vessels, and punctured twice with an 18-gauge needle on the antimesenteric surface. A silicon catheter (inner diameter 0.025 inch, outer diameter 0.045 inch, Dow Corning, Midland, MI, USA) was placed in the superior vena cava via the jugular vein, and physiologic saline was infused at 200 ml/kg per day. The animals were fitted with a harness and swivel so they could move without restraint, and housed in a metabolic cage.

Irrigation of the Peritoneal Cavity

Three hours after cecal ligation and puncture, the animals were prepared using the same procedure, a laparotomy was performed, the cecum was resected, and the peritoneal cavity was irrigated with 50 ml physiologic saline in Group S, and 50 ml ESAW in Group E.

Preparation of ESAW

Electrolyzed strong acid water was generated by the electrolysis of tap water containing 0.12% sodium chloride employing a Model 201 (Nihon Aqua, Kyoto, Japan; Fig. 1). Its chemical characteristics include a pH of 2.7, an oxidative-reduction potential of 1000–1100 mV, a dissolved oxygen concentration of 10–30 ppm, and a chlorine concentration of 30–40 ppm, or 1.2 mM (as hypochlorous acid).

Bacterial Count

At 6 and 18 h after cecal resection and peritoneal irrigation, half of the animals in both groups were prepared using the same procedure and subjected to a laparotomy. The ascitic fluid was collected from the Douglas pouch. The number of bacteria was counted as colony forming units (CFU/ml).

Statistical Analysis

The results were expressed as the mean ± SD. A generalized Wilcoxon test was employed for the survival rate, and Student’s t-test for the bacterial count. Statistical significance was defined as $P < 0.05$.

Results

Survival Rate

In Group S, 50% of the animals died within 1 day after surgery, and 75% died within 3 days (Fig. 2). The dead animals in Group S became ill with behavior consistent with that described by Wichterman et al. in a sepsis model, and autopsy in Group S revealed mild adhesions in the peritoneal cavity, but no purulent peritonitis, which suggested that the animals died of sepsis. An autopsy in Group E showed no remarkable change in the peritoneal cavity. The survival rate on day 5 in Groups S and E was 25% (3/12) and 85.7% (12/14), respectively, thus being significantly higher in Group E ($P < 0.01$).

![Fig. 1. Principle of electrolysis apparatus and formation of electrolyzed strong acid water. When a voltage is applied, water is electrolyzed to give an acid aqueous solution at the positive electrode and a basic aqueous solution at the negative electrode according to the following chemical formulae. On positive electrode: $\text{H}_2\text{O} \rightarrow \text{1/2O}_2+2\text{H}^++2e^-$, $2\text{Cl}^- \rightarrow \text{Cl}_2+2e^-$, $\text{Cl}_2(\text{aq})+\text{H}_2\text{O} \rightarrow \text{HCl}+\text{HClO}$; on the negative electrode: $\text{H}_2\text{O}+2e^- \rightarrow \text{1/2H}_2+\text{OH}^-$](image)

![Fig. 2. Survival curve. Animals in both groups survived the first day after the surgery. On day 5, the survival rate in Group E (85.7%) was significantly higher than that in Group S (25%) ($P < 0.01$)](image)
strong microbicidal activity inhibits the growth of not only a wide spectrum of bacteria including methicillin-resistant *Staphylococcus aureus*,\textsuperscript{2–4,17} but also viruses including human immunodeficiency virus and hepatitis B virus.\textsuperscript{6,8} Moreover, it directly inactivates endotoxin.\textsuperscript{18}

In addition to its strong microbicidal activity, ESAW has the following advantages over various chemical disinfection agents: it is minimally invasive to tissue because of its extremely low cytotoxicity,\textsuperscript{19} it is ecological because its breakdown produces only saline and traces of chlorine gas, and last but not least, it is economical because the source is just tap water and salt. Therefore, ESAW has been increasingly used as a disinfectant for medical instruments, such as hemodialysis equipment\textsuperscript{18} and endoscopes,\textsuperscript{20} and for hand disinfection,\textsuperscript{21} and its efficacy and feasibility have also been increasingly recognized in Japan. In addition, ESAW has also been applied for the irrigation of body cavities\textsuperscript{11–14} and skin ulcers.\textsuperscript{22} From the Japan National Cardiovascular Center, Hayashi et al.\textsuperscript{11} reported four cases of postoperative mediastinitis that was successfully treated with ESAW. They reported that ESAW had no adverse effects, while a satisfactory growth of healthy granulation was also observed during convalescence. A controlled study on peritoneal lavage was conducted for perforated peritonitis in pediatric patients.\textsuperscript{12} The peritoneal cavity was irrigated with 100 ml/kg normal saline or ESAW, and it was concluded that peritoneal irrigation with ESAW was safe and more effective than irrigation with saline. The peritoneal irrigation with ESAW in experimental peritonitis created by a cecal puncture also proved to be as effective as granulocyte-colony stimulation factor (G-CSF).\textsuperscript{23} Gurleyik et al.\textsuperscript{35} demonstrated that the subcutaneous injection of 50 mg/kg G-CSF increased the 4-day survival rate from 20% to 90%. Such rates are very close to those observed in the present study, from 25% to 85%. As a result, ESAW is therefore recommended for application in clinical cases; however, only a few prospective studies to establish its safety and effectiveness have so far been reported.\textsuperscript{12,14} The current study indicated that peritoneal irrigation of perforated peritonitis with ESAW is a safe and effective method for reducing residual bacteria in the ascitic fluid and could also reduce the incidence of abscess formation in the peritoneal cavity and wound infection, and consequently reduce the length of hospital stay.\textsuperscript{12}

**References**


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**Fig. 3.** Bacterial count of ascites. The bacterial counts in the ascites both at 6 and 18 h after irrigation were significantly lower in Group E than in Group S (*P < 0.001*).


