

Retrospective Study

Utilization of chest tube as an esophagus stent in pediatric caustic injuries: A retrospective study

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Abstract

BACKGROUND

The management of caustic esophageal burns in the pediatric population has changed over the years, while the most optimal management with regards to effectiveness, availability, and cost-beneficient stays controvertible.

AIM

To describe how to utilize a chest tube for esophageal stenting in pediatrics.

METHODS

Data regarding the etiology, treatment, and complications of caustic injury in pediatrics over 10 years was collected retrospectively. Furthermore, data regarding the patient's follow-up who underwent esophageal chest tube (ECT) were collected. The ECT was prepared by carving a narrowed section in the chest tube while maintaining the radiopaque section. The ECT will then be positioned from the cricopharyngeal and exited through the nostril and fixed on the patient's cheek.

RESULTS

During the period of our study, data from 57 patients with an average age of 2.5

years (range 1-12; SD = 1.7) were obtained. The results showed that 89% of esophageal injury was due to alkaline and 9.4% were caused by acidic agents. The treatment methods showed that 29 patients (50.8%) recovered with dilatation alone. In 16 patients (28.06%), the esophageal repair was performed by using the colon, and in 5 patients (8.7%), other surgical methods were used and in 7 patients (12.2%), the ECT stents were used. ECT was inserted in 7 cases with a mean age of 2 (range: 1.5-3) years who were classified as grade IIB or III. Grading was performed by endoscopy assessment on the first day. Antibiotics and corticosteroids were administrated as initial medical management for all patients. ECT implantation was done during the first 8 d for 5 out of 7 cases (mean: 3.8 d). For the 2 patients, ECT was used after 27 (patient 6) d and 83 (patient 7) d. The reason for late stenting in these patients was a postponed referral to our center, in which patient 7 even received 4 dilation episodes before visiting our center. ECT was removed after an average of 44 d in the first 5 patients, while in the other 2 patients (6 and 7) was 2 and 1 wk, respectively. There was no complication related to, or failure of, stent placement. It is worth mentioning that none of the 7 ECT cases required gastrostomy or jejunostomy.

CONCLUSION

The ECT method introduced in our study can be used as a broadly available, economic, and easy-use facility for esophageal stenting, particularly in developing countries and emergency departments which have limited access to modern equipment. Further multicenter studies with higher volume patients are required for further deployment of this method.

Key Words: Caustic injury; Pediatric; Esophageal stent; Facility; Emergency

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Core Tip: Given that caustic ingestion is one of the most common incidents in clinical practice, especially among children, we believe that our new esophageal stent is not only an accessible device but also extremely cost-benefit relative to existing Self Expandable Metallic Stents and Self-expanding Plastic Stents. We hope that this new esophageal stent, which is a modified chest tube, will help all surgeons and emergency physicians manage patients with caustic ingestion in the future, especially for those working in developing countries and areas with lower equipment accessibility.

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INTRODUCTION

Esophageal injury followed by caustic agent ingestion, also known as erosive material ingestion, is among the most challenging and prevalent problems, particularly in developing countries[1,2]. Complications vary from an asymptomatic effect to drastic outcomes such as esophageal stricture or perforation, which can be potentially fatal[3-5]. The severity of injury also depends on the type of ingested substance as well as the amount and time of tissue exposure[6,7]. Esophageal stricture is considered to be the most prevalent complication in these cases[8,9].

Children and pediatrics are among the most frequent caustic ingestion victims, which occur either due to accidental or unintentional ingestion of erosive materials[6]. It has also been reported to be more prevalent among males[10]. Furthermore, this problem is most common in toddlers with a prevalence peak of 2 years old[11,12].

Acids and alkalis are the two basic types of erosive materials; however, alkaline materials are considered the most common erosive agents in these cases[3,13]. Almost 25% of caustic ingestion is followed by exposure to personal care products or household chemicals, such as detergent agents and bleaches[3,12]. The high morbidity and mortality rate followed by these injuries make them a serious challenging issue that requires initial management for all of these patients, including airway assessment, hemodynamic stabilization, and electrolyte replacement, followed by prescribing corticosteroids and antibiotics[14,15].

Using esophageal stenting to prevent or reduce future stricture formation is very controversial, with no pediatric-specific esophageal stents available or clear guidelines for their use.

The idea is to avoid contact with opposing sides to decrease adherence and following stricture formation. Even though this approach has been shown to decrease the rate of stricture formation, so far it has not been accepted as a routine clinical practice[16,17].

Some authors believed that esophageal stents are an effective method for preventing esophageal stricture in the first 48 h and also eliminating esophageal stricture recurrence followed by other dilation methods. Initial reports of outcomes following esophageal stenting described the use of a Silastic tube or polytetrafluoroethylene (PTFE) rod, both secured at the nose[18-20]. More recently, the use of self-expanding stents placed either endoscopically or under fluoroscopic guidance has been described. Plastic, metal, and biodegradable self-expanding stents have been used for esophageal strictures in children; however, the effectiveness, expensiveness, accessibility, and problems that these stents cause for the patients are still challenging issues[21-23].

Therefore, in this study, we aimed to introduce a new esophageal stenting method by utilizing a chest tube as an available and accessible device in emergency departments for patients suffering from caustic injuries. We also reviewed the etiology of caustic injury pediatrics in southern west Iran and the outcome of several patients treated with this Technique.

MATERIALS AND METHODS

Study design and participant selection

In this retrospective study, hospital records during ten years of patients aged under 18 years old who were admitted due to caustic chemical ingestion at the authors' affiliated hospital, which is a referral center for pediatric injuries, were collected. Data regarding the patient's characteristics, age, cause of the burn, degree of burn, treatment with antibiotics and steroids, use of gastrostomy and jejunostomy, number of dilatations and intervals, surgeries performed, and their complications (anastomotic leakage, esophageal rupture, adhesions, other early and late complications which were in associated to burns) was also gathered.

Various endoscopic grading is available and Zargar's classification is one of the most commonly used. In his study, Zargar *et al*[24] found all patients with grade 0, I and IIA burns recovered without sequelae. The majority of grade IIB and all survivors with grade III injury developed eventual esophageal or gastric cicatrization[24].

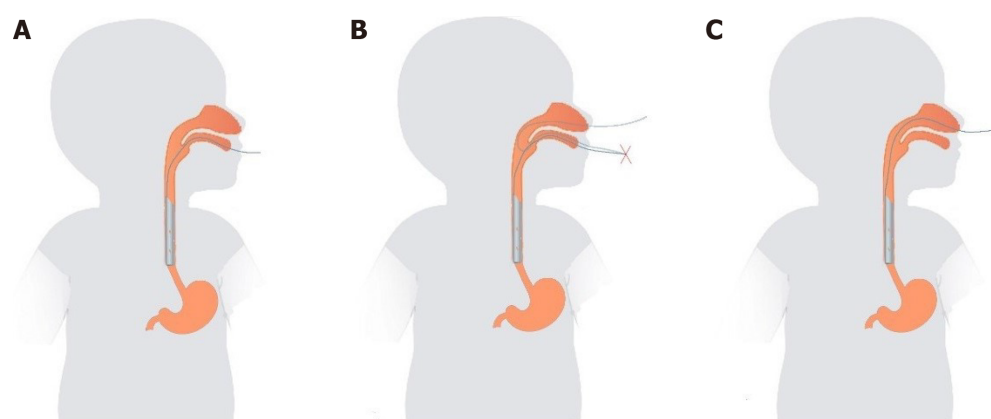
In our study esophageal stent was utilized in those with grades IIB and III.

The story and method of esophageal chest tube stenting

During several years of our clinical experiences, we found that esophageal stricture has developed frequently after caustic ingestion in those who have higher grades of corrosive injuries based on the endoscopically reports. We found that esophageal stents may prevent stricture significantly; however, the recently introduced self-expanding stents were so limited and expensive in our country; and many other low-income regions. Moreover, necrosis, ulceration, tissue hyperplasia, and fistula formation have been frequently reported by self-expandable metallic stents. After re-evaluating the patient's information, we found that esophageal stricture mostly developed in higher stages of injury (stage IIB and above). There were several recommendations from conservative management and medical therapy (such as steroids) to invasive methods; however, none of them had been proven. Therefore, we start to search for a costly and broadly available device. We consider the chest tube as an esophageal stent which may help; however, there were several concerns about it. The expected complication could be more similar to a plastic stent rather than a metal stent. Plastic stents are said to have lesser tissue hyperplasia but with a higher rate of stent migration and a lower tendency to sustain the significant radial force. Regarding the aforementioned concern, we used the radiopaque section of the chest tube to follow its place after insertion. Likewise, the external part of ECT exited the nose and fixed it to the patient's cheek using tape. Furthermore, we were afraid of the insertion procedure may lead to esophageal perforation, therefore, we placed it *via* endoscopy through a guide wire. Likewise, we didn't consider the injuries of stage IV due to its higher tendency for perforation. Moreover, we applied the anti-reflux medication and encourage the patient to elevate the head of their bed.

In this method, the esophageal chest tube (ECT) stent is inserted either in the first 48-72 h after a caustic injury or precisely after dilatation and is removed after 6-8 wk. In this technique, we utilize the ECT in three steps.

First, the chest tube's length is measured concerning age, weight, and the stature of each patient. We used different sizes of chest tubes based on the physician's preference according to the initial endoscopic evaluation. Sedative and analgesic medications were also applied. Afterward, a narrowed section is shaped by obliquely carving the chest tube and maintaining the radiopaque section, which will be positioned from the cricopharyngeal until the external section of the tube. After preparing the ECT, the tube will be inserted orally *via* endoscopy through a guide wire, with the narrow end positioned out of the mouth (Figure 1A). Following the ECT insertion, we aim to exit it through the nasal cannula, in which we use either a Nelaton or nasogastric tube. In this regard, we insert the tube through the nasal cannula so that it exits the mouth while keeping the proximal section out of the nose.



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Figure 1 Utilizing a chest tube as an esophageal stent in caustic injury in pediatrics. A: Insertion of esophageal chest tube (ECT) from cricopharyngeal until lower sphincter and exiting the external part from the mouth; B: Suturing the external part of the ECT to a Nelaton or nasogastric tube which has been passed through the nostrils; C: Exiting the external part of the ECT through the nostrils.

Subsequently, the end part of the tube is sutured to the distant narrow part of the ECT (**Figure 1B**). Therefore, by pulling onto the proximal part of the tube, it will act as a guide for the ECT to extract it through the nasal cannula (**Figure 1C**). Consequently, the ECT will exit the nose and be fixed to the patient's cheek using tape. (**Figure 2**). Also, by preserving the radiopaque section of the ECT, monitoring the position of the tube is possible through chest radiography. (**Figure 3**).

Follow-up evaluation

Then patients were evaluated for early complications such as pneumonia, pneumothorax, esophageal rupture, *etc.*, or late complications such as esophageal stricture, gastroesophageal reflux, and the need for colon interposition.

RESULTS

During the period of our study, data from 57 patients with an average age of 2.5 years (range 1-12; SD = 1.7) were obtained. The results showed that 89% of esophageal injury was due to alkaline and 9.4% were caused by acidic agents. **Table 1** demonstrates the etiology factors of the patients in our study.

The treatment methods showed that 29 patients (50.8%) recovered with dilatation alone. In 16 patients (28.06%), the esophageal repair was performed by using the colon, and in 5 patients (8.7%), other surgical methods were used and in 7 patients (12.2%), the ECT stents were used.

ECT was inserted in 7 cases with a mean age of 2 (range: 1.5-3) years who were classified as grade IIB or III. Grading was performed by endoscopy assessment on the first day. Antibiotics and corticosteroids were administrated as initial medical management for all patients. ECT implantation was done during the first 8 d for 5 out of 7 cases (mean: 3.8 d). For the 2 patients, ECT was used after 27 (patient 6) d and 83 (patient 7) d. The reason for late stenting in these patients was a postponed referral to our center, in which patient 7 even received 4 dilation episodes before visiting our center. ECT was removed after an average of 44 d in the first 5 patients, while in the other 2 patients (6 and 7) was 2 and 1 wk, respectively.

There was no complication related to, or failure of, stent placement. It is worth mentioning that none of the 7 ECT cases required gastrostomy or jejunostomy. **Table 2** summarized information on patients managed with esophageal stenting using a chest tube.

DISCUSSION

Caustic injuries are considered one of the most prevalent, as well as preventable accidental injuries. Children are among the highest groups at risk of these injuries due to their curiosity and ability to reach objects without discerning their harm and potential dangers[25,26]. In 2009, the Kids' Inpatient Database of the United States reported 807 cases of caustic injuries. Our study was conducted in southwest Iran, in which 57 pediatric hospitalized patients with caustic injuries were collected for 10 years (1994-2003), demonstrating an annual rate of 5.7 cases/year. In similar studies in our province, Honar *et al*[27] reported 75 in 2006-2011 (12.5 case/year) and Dehghani *et al*[10] reported 41 cases from 2015-2016 (20.5 cases/year). This upsurge in the number of cases shows the significance of this matter and therefore, evaluating the etiology and applied management, along with choosing the proper therapeutic option for

Table 1 Etiological features of caustic injury among pediatrics in southern west Iran

Variable	Frequency, <i>n</i> = 57	Percentage (%)
Etiology		
Caustic Soda	47	83.3
Stove-top cleaner	3	5.7
Acid	3	5.7
Hydrochloric acid	2	3.7
Boiled water	2	3.7
Medical treatment		
Antibiotic Therapy	36	66.7
Corticosteroids	22	40.7
Advanced treatment		
Dilatation	29	50.8
Stent insertion	7	12
Colon interposition	16	28
Other surgical methods	5	8.7
Surgical treatment		
Gastrostomy	19	33.3
Jejunostomy	4	7.4
Complication		
No complication	39	69.6
Pneumothorax	11	19
Esophageal rupture	6	11.4

Table 2 Caustic injury pediatrics treated with esophageal stenting using a chest tube

Variable	Patient						
	1	2	3	4	5	6	7
Age (mo)	24	24	18	36	24	30	34
Grade	III	IIB	IIB	IIB	III	IIB	IIB
Etiology	Caustic soda	Hydrochloric acid	Acid	Acid	Caustic soda	Stove cleaner	Caustic soda
Time of esophageal chest tube insertion (after injury)	1	6	8	2	1	27	83
Esophageal chest tube duration	27	35	50	90	20	16	7
Replacement (Frequency)	1:14	-	2:12 and 22	2: 30 and 60	-	1: 9	1: 4
Surgical intervention	-	-	-	-	Colon Interposition	-	-
Duration of follow-up (mo)	23	22	16	6	35	15	14
Patient Satisfaction	Satisfied	Satisfied	Satisfied	Mild esophageal stenosis	Satisfied	Satisfied	Mild esophageal stenosis

these patients is necessary.

Among the contributing factors to this increasing number of cases per year may be the increased use, easy accessibility, and low cost of detergents and bleaches, especially in developing countries. Alkaline was considered the most corrosive agent in this study with an incidence of 89% (50 out of 57 cases), while acid agents consisted of 9.4% (5 out of 57 cases) of the etiologies in our study population. In a



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Figure 2 Esophageal chest tube. A: Esophageal chest tube prepared for a 6-year-old boy with a caustic injury; B: Esophageal chest tube fixed for a 6-year-old boy with a caustic injury.



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Figure 3 Chest X-ray, Chest radiography demonstrating and esophageal chest tube inserted for a patient with a caustic injury.

similar study in our center, 64 hospitalized patients were reported to have had alkaline ingestion for 4 years[11]. Also, in a study conducted in Australia, 74% of caustic ingestion occurred by alkaline agents [28]. Acids, regarding their low viscosity and therefore rapid transfer to the stomach and also due to their nature cause coagulation necrosis, with eschar formation that may prevent further damage and limit the injury depth. Conversely, alkalis bind to tissue proteins and lead to liquefactive necrosis and saponification, and penetrate deeper into tissues, assisted by a higher viscosity and a longer contact time through the esophagus. On the other hand, children usually tend to swallow a larger amount of alkaline because alkalis are usually odorless and tasteless; although, acidic agents have a sour taste which makes children spit them out. Another point for our region (the south of Iran) is the excessive use of air conditioners followed by its cleaner that fundamentally and are made by NaOH which kept in beverage bottles without any warning label in addition to the low educational level of parents have led to increasing the occurrence of esophageal burn by caustic ingestion.

In caustic injury patients, a preliminary survey includes airway assessment as well as fluid and electrolyte balance[12]. We also administered antibiotics along with corticosteroids as medical management. Among the most imperative complications of esophageal burns is a stricture. Katz *et al*[9] reported esophageal stricture in more than 90% of patients with grade 3 and almost 30%-70% of grade 2B caustic injury. Malignant transformation to esophageal cancer is one of the following complications of esophageal stricture[29]. Studies have also reported that esophageal stricture is associated with hiatal hernia, reflux disease, dysphagia symptoms, and causing difficulties for esophageal reconstruction[30-32]. A study in 1992 evaluated the administration efficacy of antibiotic and systemic steroids simultaneously in caustic ingestion, which concluded that antibiotics with steroids might be useful in reducing strictures in patients with esophageal burns[33]. Controversially, a controlled randomized trial revealed the corticosteroids' ineffectiveness in preventing esophageal stricture in children with a caustic injury [34]. Therefore, novel therapeutic approaches for preventing or managing esophageal strictures that would enable a child to tolerate an oral diet in a more expeditious and less invasive manner would be highly desirable. Furthermore, the oblique cutting of the ECT facilitates feeding and also prevents unintentional aspiration.

In this report, we utilized the chest tube, as a broadly available and well-known equipment in all emergency departments, proposed as an esophageal stent for not only preventing esophageal stricture in the first 48 h but also after dilatation. Formerly, self-expanding plastic stents (SEPS) and fully covered self-expanding metal stents (FCSEMS) have been used for stenting, and each had its advantage and disadvantage. The success rate for SEPS showed 50% by Broto *et al*[21] and 75% for FCSEMS by Zhang *et al*[22].

Stent migration is another common complication that has been reported in 14% to 48% of cases, which has been related to the type of stent[35]. Metal stents that are fully covered with PTFE, polyurethane, or silicone have a higher chance of migration, compared with uncovered metal stents, which are held in place by hyper-granulation and mucosal ingrowth; nevertheless, these proliferations contribute to ulcers and struggle when removing the stent[36,37]. Self-expanding plastic stents are at greater risk of migration when compared with self-expanding metal stents, which are daunted in benign esophageal stenosis due to their high incidence of necrosis and ulceration, tissue hyperplasia, new stricture or fistula formation, and the tendency for the metal portion to embed within the esophageal wall[38,39]. Best *et al*[40] and Manfredi *et al*[39] reported high rates of mucosal ingrowth and hyper-granulation, causing difficulty in stent removal and stent-induced ulceration. Since the ECT is inserted from below the cricopharyngeal till the lower esophagus sphincter and also fixed from outside of the nose, this decreases the chance of migration compared to other methods of fixation using thread and suture. Furthermore, the stent material safeguards cell proliferation into the stent, resulting in easy removal of the ECT and less complication such as esophageal ulcers and hyper-granulation.

From an economic point of view, as one of the most important factors in management decision making particularly in developing countries, the proposed ECT can be an ideal choice due to its cost-effective aspects and in centers where other esophageal stents are unavailable.

Among the other advantages of the ECT is that the patient will be able to tolerate oral feeding with soft diets as well as liquids, so the foods are based on the inlet of the ECT, which is located in the cricopharyngeal area and allows a pathway to the stomach. However, since the ECT covers the total length of the esophagus to the lower sphincter, a risk of reflux should be considered which can be managed with proper anti-reflux medication.

Among the patients in our study, 5 were satisfied with their results, while two (patients 4 and 7) had mild esophageal stenosis. Among these two, patient 4 had ECT for 90 d. The exact duration in which stents should be used is still a matter of debate. The European Society for Gastrointestinal Endoscopy Recommendations for the Stenting of Benign Esophageal Strictures acknowledges this lack of data available and suggests the insertion of self-expanding metal and plastic stents for a minimum of 6-8 wk and no more than three mo[41]. Likewise, we recommend removing the ECT after 6-8 wk. Furthermore, patient 7 had ECT inserted 83 d after the injury, which had already caused chronic damage and stricture. It is also worth mentioning that ECT was inserted in one of the patients with grade I caustic injury, which was intended as prophylaxis for esophageal stenosis.

Endoscopic dilatation with a balloon has been the standard of treatment for benign esophageal strictures; nevertheless, the recurrence rate was reported to be 30%-40%[38]. Increasing the victims of caustic ingestion on one hand, and the high economic burden, on the other hand, made us use the ECT in early stenting, which is more economical, broadly available, and also regarding its high efficacy. In this study, we just want to report our experience in a referral center in a low-income country. Of course, there is an inevitable need to examine it during the trials. Also, we don't recommend this in the situation that another stent is available.

Limitations

Several caveats regarding our study deserve mention. First, this was a retrospective, single-institution series of esophageal stents deployed in a heterogeneous group of patients. Also, our series lack of control group and consists of a small sample size. This study was non-comparative and did not compare stenting to other therapeutic options. However, our study's main focus was utilizing an already existing device, the chest tube, as an esophageal stent for the early management of caustic injury pediatrics, especially in centers with limited equipment.

CONCLUSION

Caustic injury and its management are among the most challenging problems among pediatric surgeons. The availability, efficiency, and economic aspect of materials are important factors that should be taken into consideration in planning the therapeutic approach for these patients. In this study, we successfully report utilizing a chest tube, as an available device in almost every emergency department, as a method for esophageal stenting. This method should especially be considered in developing countries with limited utilities and also emergency departments and centers with restricted access to modern equipment.

ARTICLE HIGHLIGHTS

Research background

Using esophageal stenting for future stricture formation prevention is very controversial, with no clear guidelines for their use. The idea is to avoid contact with opposing sides to decrease adherence and following stricture formation. Even though this approach has been shown to decrease the rate of stricture formation.

Research Motivation

Different stents have been introduced so far, however, the effectiveness, expensiveness, accessibility, and problems that these stents cause for the patients are still challenging issues.

Research objectives

To introduce a new esophageal stenting method by utilizing a chest tube as an available and accessible device in emergency departments for patients suffering from caustic injuries.

Research methods

Collect demographic data of children with caustic injuries respectively, patients who had stage IIB and III of corrosive injuries were eligible for esophageal chest tube insertion.

Research results

Twenty-nine patients (50.8%) recovered with dilatation alone, 16 needed esophageal repair, and an esophageal chest tube (ECT) was inserted for 7 patients. None of the 7 ECT cases required gastrostomy or jejunostomy.

Research conclusions

We successfully report utilizing a chest tube, as an available device in almost every emergency department, as a method for esophageal stenting. This method is could be an alternative in developing countries with limited utilities as well as centers with restricted access to modern equipment.

Research perspectives

The chest tube has many advantages, it has a radiopaque line that could be used to monitor it, and patients could get an oral diet after stabilization. it is also costly and broadly available. By keeping the advantage and improving its problem, it could be used more efficiently. Moreover, it should be examined during different trials.

FOOTNOTES

Author contributions: Foroutan H designed and performed the research; Salimi M and Hosseinpour H designed the research and wrote the paper; Shahriarirad R designed the research and supervised the report; Esfandiari S designed the research and contributed to the analysis; Pooresmaeel F and Sarejloo S provided clinical advice.

Institutional review board statement: This study was reviewed and approved by the Ethics Committee of the Shiraz University of Medical Sciences.

Informed consent statement: Written informed consent was obtained from the patients' parent/guardian in our study. The purpose of this research was completely explained to the patient's parents/guardian and was assured that their information will be kept confidential by the researcher. The present study was approved by the Medical Ethics Committee of Shiraz University of Medical Sciences. Consent was obtained from the patient parent/guardian regarding the publication of this study.

Conflict-of-interest statement: All authors have no financial relationships to disclose.

Data sharing statement: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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