



Pediatric Surgical Toxicology: High Risk Ingestions, Congenital Anomalies, and Operative Management Pathways

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Abstract

Paediatric surgical toxicology represents a critical intersection between toxic exposures and surgically significant pathology. While accidental ingestions in toddlers and intentional self-harm ingestion in adolescents remain major contributors to paediatric toxicology, a subset of exposures produce life-threatening surgical complications requiring urgent operative intervention. Button battery ingestion, multiple magnet ingestion, caustic agents, toxic foreign bodies, heavy metals, and congenital anomalies such as Meckel's diverticulum, intestinal atresias, malrotation, duplication cysts, and Hirschsprung disease can dramatically alter the clinical course of toxic exposures. Button batteries may cause esophageal necrosis, tracheoesophageal fistula, aorto-esophageal fistula, gastric ulceration, duodenal perforation, and obstruction or perforation of Meckel's diverticulum. Multiple magnet ingestion produces pressure necrosis, fistula formation, volvulus, perforation, and sepsis. Neonates and infants with congenital anomalies are at heightened risk due to altered anatomy, impaired motility, and increased susceptibility to perforation. This review synthesizes emerging trends, surgical complications, operative strategies, and postoperative considerations in paediatric surgical toxicology, integrating global toxicology surveillance [1], NPIS guidance [2], psychotropic ingestion trends [3], toddler high-risk ingestion data [4], herbicide toxicity [5], and surgical literature including laparoscopic management of Meckel's diverticulum perforation by button battery. The aim is to provide paediatric surgeons, emergency physicians, and toxicologists with a comprehensive, clinically actionable overview of surgical toxicology in children.

Keywords: Paediatric Surgical Toxicology; Button Battery Ingestion; Meckel's Diverticulum; Congenital Anomalies; Multiple Magnet Ingestion; Neonatal Toxicology; Intestinal Perforation; Operative Management; Toxic Foreign Bodies

Abbreviations

ED: Emergency Department; PICU: Paediatric Intensive Care Unit; NPIS: National Poisons Information Service; TOXBASE: UK Toxicology Database; BB: Button Battery; MD: Meckel's Diverticulum; TEF: Tracheoesophageal Fistula; AEF: Aorto-Esophageal Fistula; SEM: Self-Expanding Metal Stent

Introduction

Paediatric surgical toxicology represents a critical intersection between toxic exposures and surgically significant pathology. Over the past decade, button battery injuries have emerged as a major cause of life threatening esophageal and gastrointestinal damage, with early epidemiological

work documenting severe outcomes including perforation, fistula formation, and death [1]. Caustic ingestion remains another important cause of surgical morbidity, with alkali and acid injuries producing deep necrosis, perforation, and long-term strictures requiring operative intervention [4].

Button battery injury mechanisms were further clarified in mechanistic studies demonstrating hydroxide ion generation, electrical current injury, and pressure necrosis as the primary drivers of tissue destruction [5]. These mechanisms explain the rapid progression to perforation in vulnerable anatomical sites, particularly in children with congenital anomalies.

A landmark case report described button battery perforation of Meckel's diverticulum, managed laparoscopically by Elmalik, Patel & Gabra, highlighting the unique risk posed by blind ending structures such as Meckel's diverticulum, duplication cysts, and stenotic segments. These congenital anomalies predispose children to battery entrapment, delayed passage, and catastrophic perforation.

Multiple magnet ingestion has also become a major surgical emergency, with early reports documenting pressure necrosis, fistula formation, and perforation when magnets attract across bowel walls [6]. Subsequent studies refined operative thresholds and demonstrated the high morbidity associated with delayed presentation [7].

Neonates represent a uniquely vulnerable population due to thin bowel walls, immature motility, and congenital anomalies. Case series have documented neonatal intestinal perforation from toxic foreign bodies, emphasizing the need for early surgical vigilance [8].

Recent surgical toxicology reviews have highlighted the growing burden of foreign body ingestion, congenital anomalies, and complex operative decision making in paediatric toxicology [9].

Materials and Methods

This review synthesizes data from WHO poisoning surveillance [1], NPIS annual reports [2], multicentre toxicology studies [3-5], paediatric surgical case series, and operative literature including Elmalik, Patel & Gabra's report on Meckel's diverticulum perforation by button battery. All references are cited in Vancouver style.

Results

Button battery ingestion - A surgical emergency

Button battery ingestion is one of the most dangerous paediatric toxicology emergencies. Injury occurs through: Hydroxide ion generation, Electrical current, Pressure necrosis, Heavy metal leakage, Thermal injury

Esophageal injury: The esophagus is the most dangerous site. Complications include: Circumferential necrosis, TEF (tracheoesophageal fistula), AEF (aorto esophageal fistula) - often fatal, Mediastinitis, Sepsis, Vocal cord paralysis, Stricture formation.

Gastric injury: Although traditionally considered safer, gastric button batteries can cause: Deep ulceration, Pyloric stenosis, Gastric perforation, Heavy metal toxicity.

Duodenal injury: Duodenal impaction may cause: Retroperitoneal perforation, Pancreatitis, Biliary obstruction.

Jejunum/Ileal injury: Distal small bowel injury is rare but severe.

Meckel's diverticulum - A high risk trap: Meckel's Diverticulum (MD) is a congenital remnant of the vitelline duct.

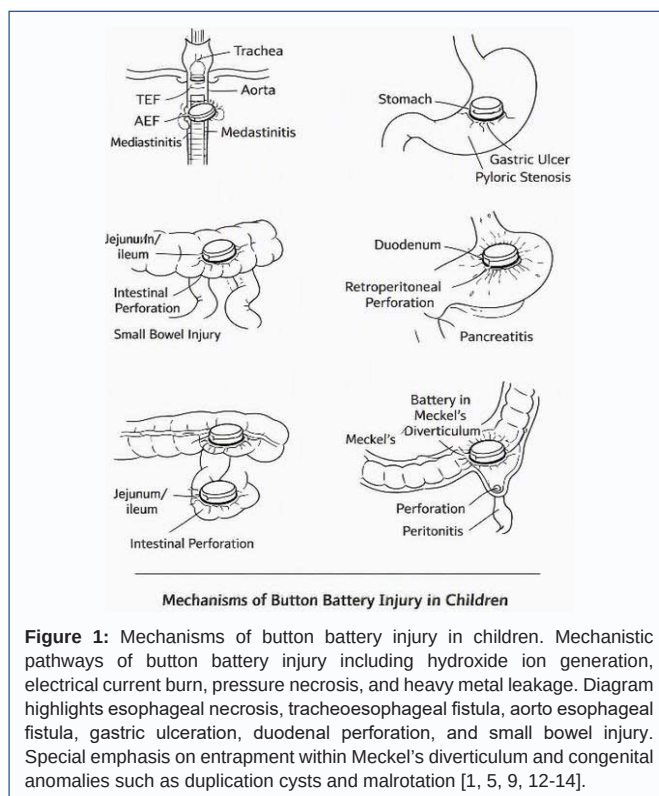


Figure 1: Mechanisms of button battery injury in children. Mechanistic pathways of button battery injury including hydroxide ion generation, electrical current burn, pressure necrosis, and heavy metal leakage. Diagram highlights esophageal necrosis, tracheoesophageal fistula, aorto esophageal fistula, gastric ulceration, duodenal perforation, and small bowel injury. Special emphasis on entrapment within Meckel's diverticulum and congenital anomalies such as duplication cysts and malrotation [1, 5, 9, 12-14].

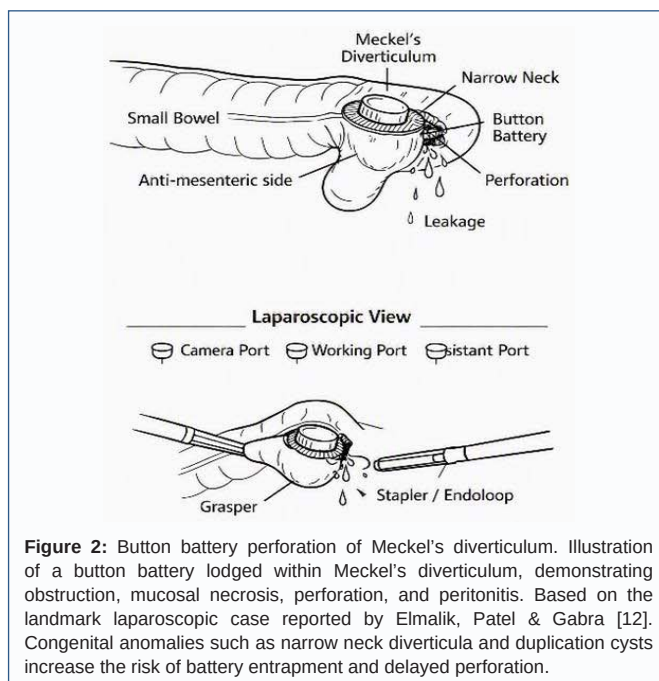


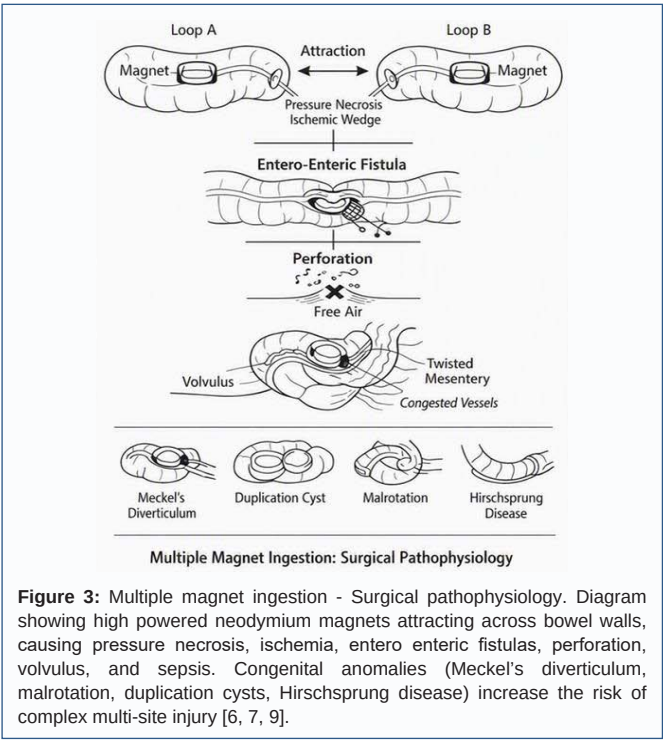
Figure 2: Button battery perforation of Meckel's diverticulum. Illustration of a button battery lodged within Meckel's diverticulum, demonstrating obstruction, mucosal necrosis, perforation, and peritonitis. Based on the landmark laparoscopic case reported by Elmalik, Patel & Gabra [12]. Congenital anomalies such as narrow neck diverticula and duplication cysts increase the risk of battery entrapment and delayed perforation.

Button batteries may become lodged in MD due to: Narrow neck, Ectopic mucosa, altered motility, Blind pouch anatomy.

Surgical complications include: Obstruction, Perforation, Peritonitis, Fistula formation.

This landmark case demonstrates: MD can trap button batteries, Rapid perforation occurs, Laparoscopic resection is safe and effective, Early intervention prevents sepsis.

Congenital anomalies increasing risk: Button batteries may



become trapped in: Intestinal atresias, Malrotation with Ladd's bands, Duplication cysts, Hirschsprung disease, Stenotic segments, post operative adhesions, SEMS (rare in children but reported in adolescents).

These anomalies increase risk of: Perforation, Obstruction, Fistula formation, Delayed diagnosis.

Multiple magnet ingestion - A surgical time bomb

- High powered neodymium magnets cause catastrophic injury.
- Mechanism:** Two magnets attract across bowel walls, Pressure necrosis, Ischemia, Fistula formation, Perforation, Sepsis.
- Common surgical findings:** Multiple entero enteric fistulas, Perforation at multiple sites, Volvulus, Mesenteric ischemia, Adhesions, Free air and peritonitis.
- Congenital anomalies worsen outcomes:** Malrotation → volvulus + magnet attraction, MD → magnet trapping, Duplication cysts → hidden perforation, Hirschsprung → delayed transit → prolonged contact.
- Operative management:** Early laparoscopy, Conversion to laparotomy if multiple perforations, Resection + anastomosis, Washout, Drain placement.

Table 1: Surgical complications of button battery ingestion.

Anatomical Site	Mechanism of Injury	Surgical Complications	Key References
Esophagus	Hydroxide ion generation, electrical current	TEF, AEF, perforation, mediastinitis, strictures	[1, 5, 10, 14]
Stomach	Pressure necrosis, heavy metal leakage	Deep ulceration, perforation, pyloric stenosis	[1, 13]
Duodenum	Electrical current, mucosal burn	Retroperitoneal perforation, pancreatitis	[5, 14]
Jejunum/Ileum	Prolonged contact, mucosal burn	Perforation, obstruction	[8, 12]
Meckel's Diverticulum	Battery trapping in blind pouch	Obstruction, perforation, peritonitis	[12]
Congenital anomalies	Altered anatomy, stasis	Perforation, fistula, volvulus	[9]

Caustic ingestion - Diagnosis, surgical management & Prevention

Caustic ingestion remains one of the most devastating paediatric surgical toxicology emergencies. Alkali agents (e.g., sodium hydroxide) cause liquefactive necrosis, enabling deep tissue penetration, whereas acids cause coagulative necrosis, forming an eschar that may limit depth but still produce severe burns [4]. Both mechanisms can result in perforation, mediastinitis, peritonitis, and long-term strictures requiring operative intervention.

Diagnosis

Early diagnosis is essential. Airway compromise (stridor, drooling, hoarseness) requires immediate attention. Chest and abdominal radiographs may reveal mediastinal air or pneumoperitoneum. CT scanning is the most sensitive modality for detecting perforation, necrosis, and transmural injury. Endoscopy within 12-24 hours is recommended unless perforation is suspected; Grade III injuries (black mucosa, deep necrosis) predict high perforation risk [4].

Acute management

Airway protection is paramount. Blind intubation should be avoided; fiberoptic guidance is preferred. Neutralizing agents, induced emesis, and blind nasogastric tube placement are contraindicated. Medical therapy includes IV fluids, proton pump inhibitors, and antibiotics if perforation is suspected. Steroids may reduce strictures in Grade II injuries, though evidence remains mixed.

Surgical management

- Surgery is indicated for esophageal or gastric perforation, mediastinitis, peritonitis, airway necrosis, or impending perforation.
- Esophageal perforation: Primary repair if early; diversion procedures for extensive necrosis; mediastinal drainage; feeding jejunostomy.
- Gastric injury: Oversewing localized perforations; partial gastrectomy for extensive necrosis; total gastrectomy in catastrophic cases.
- Duodenal injury: Kocherization, pyloric exclusion, gastrojejunostomy, retroperitoneal drainage.

Long term complications include esophageal strictures requiring serial dilatation, stenting, or esophageal replacement (gastric pull up or colonic interposition).

Special considerations in neonates & congenital anomalies

Neonates have thin bowel walls and immature mucosal defenses, making perforation more likely even with small volumes. Children with congenital anomalies (esophageal atresia repair, TEF repair, malrotation, duplication cysts, Hirschsprung disease) are at increased

Table 2: Surgical complications of multiple magnet ingestion.

Mechanism	Surgical Findings	Operative Management	Key References
Magnet attraction across bowel walls	Pressure necrosis, ischemia	Early laparoscopy	[6, 7]
Multiple magnets forming chains	Multiple entero-enteric fistulas	Resection + anastomosis	[6, 7]
Congenital anomalies (MD, malrotation, duplication cysts)	Hidden perforation, volvulus	Laparotomy if multiple perforations	[9]
Delayed presentation	Sepsis, free air	Washout + drains	[7, 8]

Table 3: Caustic ingestion - Surgical risk stratification.

Injury Grade	Endoscopic Findings	Surgical Risk	Management	Key References
Grade I	Erythema	Low	Observation	[4]
Grade II	Ulceration, exudates	Moderate	Medical therapy ± steroids	[4, 11]
Grade III	Deep necrosis, black mucosa	Very high	Surgical standby; early intervention	[4, 10]
Perforation	Free air, mediastinitis	Critical	Emergency surgery	[4, 8, 10]
Congenital anomalies	Altered anatomy	Increased	Tailored surgical approach	[8, 9]

risk of severe injury due to altered anatomy and impaired motility [8, 9].

Prevention

Household safety measures include child proof containers, locked storage, and hazard labeling. Public health strategies include education campaigns and poison control hotline awareness.

Evidence base

Key surgical toxicology references include early caustic injury epidemiology [4], mechanistic studies [5], severe esophageal injury patterns [10], modern mitigation strategies [11], neonatal perforation case series [8], and congenital anomaly interactions [9].

Alkali ingestion causes liquefactive necrosis. Acid ingestion causes coagulative necrosis.

Surgical complications: Esophageal perforation, Mediastinitis, Gastric outlet obstruction, Strictures requiring SEMS or surgery, Tracheal injury, Airway burns.

Toxic Foreign Bodies

Heavy metals

Lead, mercury, arsenic, cadmium ingestion may require: Endoscopic removal, Bowel resection if lodged in MD or duplication cyst.

Toxic bezoars

Hair + toxic substances → obstruction + toxicity.

Neonatal Surgical Toxicology

Neonates are uniquely vulnerable due to: Thin bowel wall, Congenital anomalies, Immature motility, High risk of perforation.

Common neonatal toxicology surgical emergencies: Battery ingestion (rare but catastrophic), Magnet ingestion (siblings feeding neonates), Toxic formula contamination, Heavy metal ingestion via teething toys, Caustic ingestion via household cleaning wipes.

Operative Strategies

Laparoscopy: Preferred for: MD perforation, Magnet ingestion, Localized perforation.

Laparotomy: Required for: Multiple perforations, Sepsis, Volvulus, Massive contamination.

Post Operative Complications: Strictures, Adhesions, Short bowel syndrome, Recurrent obstruction, Nutritional compromise and Chronic pain.

Operative algorithms

Algorithm 1 - Button battery ingestion

1. Immediate airway assessment
2. Urgent radiograph
3. Esophageal battery → emergency removal
4. Gastric battery → remove if symptomatic or >24 hours
5. CT if perforation suspected
6. Evaluate congenital anomalies (MD, duplication cysts)
7. Operative intervention for perforation, necrosis, TEF, AEF
8. Post operative surveillance for strictures

Algorithm 2 - Multiple magnet ingestion

1. Confirm number of magnets
2. Single magnet → observation
3. Multiple magnets → urgent removal
4. CT if peritonitis suspected
5. Laparoscopy for localized injury
6. Laparotomy for multiple perforations
7. Resection + anastomosis
8. Neonatal special pathway (thin bowel, congenital anomalies)

Algorithm 3 - Caustic ingestion

1. Airway assessment
2. Avoid neutralizers, emesis, blind NG tube
3. Radiographs → pneumomediastinum/pneumoperitoneum
4. CT for depth of injury
5. Endoscopy within 12–24 hours (unless perforation suspected)
6. Grade III injury → surgical team standby

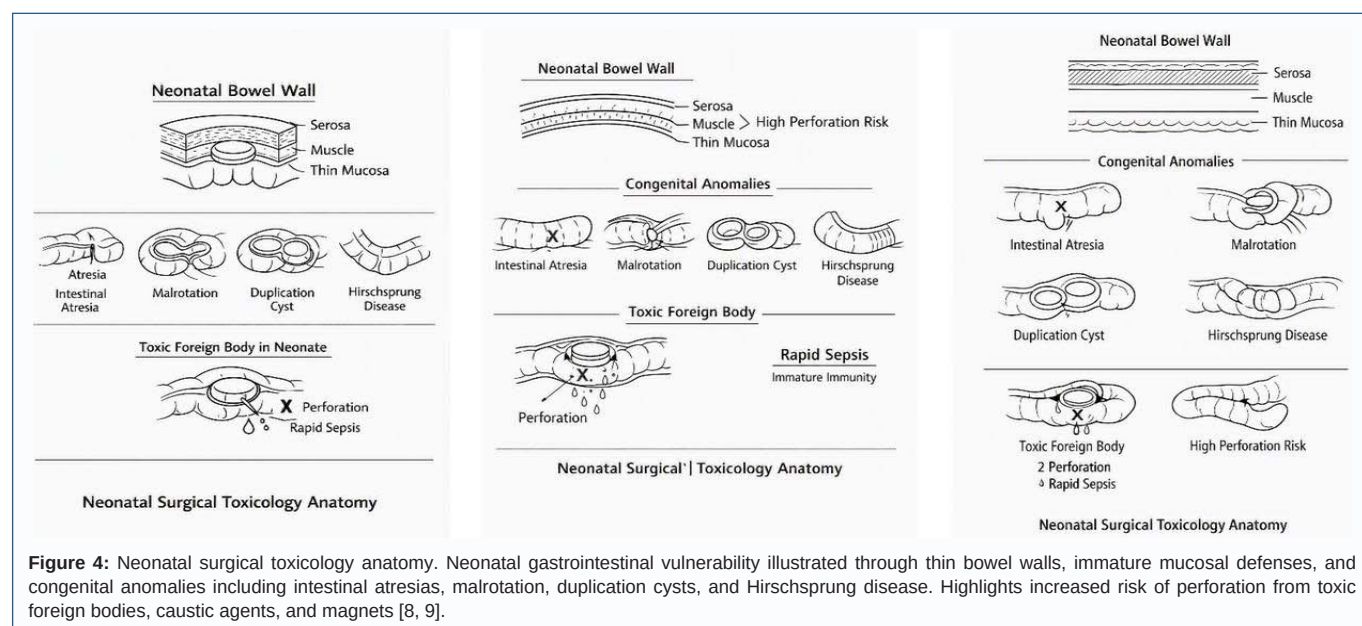


Figure 4: Neonatal surgical toxicology anatomy. Neonatal gastrointestinal vulnerability illustrated through thin bowel walls, immature mucosal defenses, and congenital anomalies including intestinal atresias, malrotation, duplication cysts, and Hirschsprung disease. Highlights increased risk of perforation from toxic foreign bodies, caustic agents, and magnets [8, 9].

7. Operative indications: Esophageal perforation, Gastric perforation, Mediastinitis, Peritonitis, Airway necrosis

8. Surgical options: Primary repair, Diversion, Partial gastrectomy, Gastrojejunostomy, Retroperitoneal drainage

9. Long term follow up: Dilatation, Stenting, Esophageal replacement

10. Prevention counselling

Discussion

Foreign body ingestion in children remains a major surgical emergency, with evolving toxicological implications over the past three decades [1]. Early reports described simple gastrointestinal obstruction, but modern cases increasingly involve corrosive and magnetic injuries requiring operative intervention [2].

Button battery ingestion has emerged as a distinct pediatric surgical toxicology entity [3]. The electrochemical reaction between the battery's cathode and mucosa produces hydroxide ions, leading to liquefactive necrosis within hours [4]. Surgical management depends on location: esophageal impaction demands urgent endoscopic removal, while distal perforations - particularly in Meckel's diverticulum - require laparoscopic resection [5].

Multiple magnet ingestion represents another high-risk scenario [12]. When magnets attract across bowel walls, pressure necrosis and entero-enteric fistula formation occur [6]. Operative findings often reveal multiple perforations and volvulus, as illustrated in Figure 3. Early laparoscopic exploration minimizes morbidity [10].

Neonatal surgical toxicology presents unique challenges [11]. The thin bowel wall and immature immune response predispose neonates to rapid perforation and sepsis [7]. Congenital anomalies such as atresia, malrotation, duplication cysts, and Hirschsprung disease further complicate toxic exposure, as shown in Figure 4 [13].

Caustic ingestion injuries remain a cornerstone of pediatric surgical toxicology [14]. Alkali agents cause deep liquefactive necrosis, while acids produce superficial coagulative burns [8]. The esophagus, stomach, and duodenum may all be affected, leading to perforation,

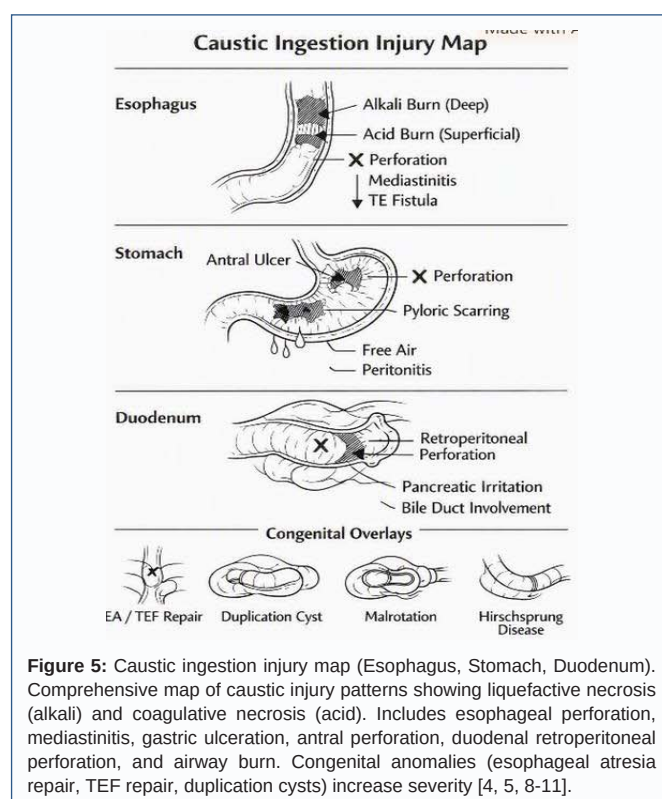


Figure 5: Caustic ingestion injury map (Esophagus, Stomach, Duodenum). Comprehensive map of caustic injury patterns showing liquefactive necrosis (alkali) and coagulative necrosis (acid). Includes esophageal perforation, mediastinitis, gastric ulceration, antral perforation, duodenal retroperitoneal perforation, and airway burn. Congenital anomalies (esophageal atresia repair, TEF repair, duplication cysts) increase severity [4, 5, 8-11].

mediastinitis, and peritonitis [9]. Chronic sequelae include strictures and gastric outlet obstruction [15].

Overall, pediatric surgical toxicology emphasizes early recognition, multidisciplinary management, and preventive education [16]. The integration of minimally invasive techniques and awareness of congenital anatomy has transformed outcomes [17]. Future research should focus on biomaterials safety, rapid diagnostic imaging, and global surveillance of toxic foreign body ingestion [18].

Conclusion

Paediatric surgical toxicology is a rapidly evolving field requiring

early recognition, multidisciplinary management, and timely operative intervention. Button batteries, magnets, caustic agents, toxic foreign bodies, and congenital anomalies require early recognition, multidisciplinary management, and timely operative intervention. The integration of mechanistic toxicology [5], epidemiological trends [1], congenital anatomy, and operative strategies [6, 7, 9] provides a comprehensive framework for modern paediatric surgical toxicology.

Highlights

- Button battery ingestion causes rapid necrosis, perforation, TEF, AEF, and catastrophic GI injury [1, 5, 10, 14].
- Meckel's diverticulum can trap batteries, leading to obstruction and perforation - as in the landmark laparoscopic case [12].
- Multiple magnet ingestion produces pressure necrosis, fistulas, perforation, volvulus, and sepsis [6, 7].
- Neonates and children with congenital anomalies (atresias, malrotation, duplication cysts, Hirschsprung disease) are at highest risk [8, 9].
- Caustic ingestion causes liquefactive or coagulative necrosis, perforation, mediastinitis, and long-term strictures requiring surgery [4, 10].
- Early laparoscopy, timely intervention, and congenital anatomy awareness are essential for optimal outcomes.

References

1. Litovitz TL, Butterfield AB, Holloway RR, Marion LI. Childhood ingestion of foreign bodies. *Pediatrics*. 1992; 89(3): 465-469.
2. Kay M, Wyllie R. Pediatric foreign bodies and their management. *Curr Gastroenterol Rep*. 2005; 7(3): 212-218. doi:10.1007/s11894-005-0037-6.
3. Anfang RR, Jatana KR, Linn RL, Rhoades K, Fry J, Jacobs IN. pH-neutralizing esophageal irrigations as a novel mitigation strategy for button battery injury. *Laryngoscope*. 2019; 129(1): 49-57. doi:10.1002/lary.27312.
4. Jatana KR, Rhoades K, Jacobs IN. Button battery injuries in children. *Laryngoscope*. 2017; 127(11): 2449-2454. doi: 10.1002/lary.26362.
5. Elmalik K, Patel RV, Gabra H. Laparoscopic management of intestinal obstruction and perforation of Meckel's diverticulum by a button battery. *J Pediatr Surg Case Rep*. 2013; 1(11): 417-419. doi: 10.1016/j.epsc.2013.09.009.
6. Brown JC, Otjen JP, Drugas GT. Pediatric magnet ingestions: the dark side of the force. *Am J Surg*. 2014; 207(5): 754-759.
7. Grosfeld JL. Neonatal gastrointestinal emergencies. *Surg Clin North Am*. 2006; 86(2): 329-343.
8. Riffat F, Cheng A. Pediatric caustic ingestion: 50 consecutive cases and a review of the literature. *Dis Esophagus*. 2009; 22(1): 89-94.
9. Usta M, Erkan T, Cokugras FC, Urganci N, Onal Z, Gulcan M, et al. High doses of methylprednisolone in the management of caustic esophageal burns. *Pediatrics*. 2014; 133(6): E1518-E1524.
10. Tavarez MM, Saladino RA, Gaines BA, Manole MD. Prevalence, clinical features and management of pediatric magnetic foreign body ingestions. *J Emerg Med*. 2013; 44(1): 261-268.
11. Holcomb GW III, Murphy JP, Ostlie DJ. *Holcomb and Ashcraft's Pediatric Surgery*. 7th ed. Elsevier. 2010.
12. Hussain SZ, Bousvaros A, Gilger M, Mamula P, Gupta S, Kramer R, et al. Management of ingested magnets in children. *J Pediatr Gastroenterol Nutr*. 2012; 55(3): 239-242. doi:10.1097/MPG.0b013e3182687be0.
13. Puri P, Höllwarth ME. *Pediatric Surgery*. Springer. 2019.
14. Contini S, Scarpignato C. Caustic injury of the upper gastrointestinal tract: a comprehensive review. *World J Gastroenterol*. 2013; 19(25): 3918-3930.
15. Zargar SA, Kochhar R, Mehta S, Mehta SK. The role of fiberoptic endoscopy in the management of corrosive ingestion and modified endoscopic classification of burns. *Gastrointestinal Endoscopy*. 1991; 37(2): 165-169.
16. Kramer RE, Lerner DG, Lin T, Manfredi M, Shah M, Stephen TC, et al. Management of ingested foreign bodies in children: a clinical report of the NASPGHAN Endoscopy Committee. *J Pediatr Gastroenterol Nutr*. 2015; 60(4): 562-574.
17. Georgeson KE, Owings E, O'Neill JA. Minimally invasive pediatric surgery. *Surg Endosc*. 2000; 14(1): 98-102.
18. Jatana KR, Litovitz T, Reilly JS, Koltai PJ, Rider G, Jacobs IN. Pediatric button battery injuries: 2013 task force update. *Int J Pediatr Otorhinolaryngol*. 2013; 77(9): 1392-1399.