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Regression Analysis of Preoperative Chest Radiographs to Predict Intraoperative Location of Esophageal Foreign Body (Coin) in Pediatric Patients

ABSTRACT

Objectives: To provide a guide to estimate the location of coins within the esophagus based on the pre-operative radiographic image among pediatric patients seen at the East Avenue Medical Center Department of Otorhinolaryngology – Head and Neck Surgery (ORL-HNS) between January 2018 and December 2020.

Methods:

Design: Retrospective Case Series

Setting: Tertiary Government Training Hospital

Participants: The records of 99 pediatric patients aged 6 months to 13 years who were diagnosed with esophageal foreign body (coin) impaction and underwent rigid esophagoscopy from January 2018 to December 2020 were retrospectively reviewed.

Results: A predictive model was derived from the data using linear regression analysis. The model shows that we can predict the intraoperative location of coin within the esophagus if provided with the patient's age and vertebral level of the coin on chest radiograph. Prediction values were reported for patients in three age categories (less than 3 years old, 3 to 7 years old, 8 to 13 years old), at 10 radiographic locations (C2, C4, C5, C6, C7, T1, T2, T3, T7, T8), except for these (C1, C3, T4-T6) because of lack of data. For example, the table predicts that a coin will be located 13 cm (or between 11.4cm to 14.8cm) from the central maxillary incisors (CMI) intraoperatively if the coin was located at level C6 vertebrae on chest radiograph, for patients less than 3 years old.

Conclusion: This study provides a novel guide that may serve as a practical tool for ENT surgeons to estimate the intraoperative location of coin foreign bodies in the esophagus of pediatric patients based on preoperative radiographic imaging.

Keywords: *foreign body; foreign object; foreign objects; foreign body ingestion; coin ingestion; esophagus; esophagoscope; esophagoscopic surgery; esophagoscopic surgical procedures*

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Philipp J Otolaryngol Head Neck Surg 2024; 39 (2):21-25

Foreign body ingestion is a common reason for patients especially children, to present in the emergency department.[1] Although most cases of foreign body ingestion can present without symptoms, some will arrive at the emergency room with complaints such as vomiting, pain or difficulty upon swallowing, and hypersalivation among the most common.[2] The most commonly ingested foreign bodies are coins.[1,3-9] In cases seen at the emergency department, a prompt investigation for accurate localization of the foreign body is important because the management is based on its location.[10,11]

Radiographs can confirm the ingestion of foreign body, identify its location, size, and shape, and help exclude foreign body aspiration.[12] The recommendation for children with a clear history of suspected or witnessed ingestion of a coin is to undergo an antero-posterior (AP) chest radiograph,[1] while for patients with an unknown foreign body or undifferentiated history, several studies recommend including lateral radiographs.[12-14] There is scarce literature relating to the difference of chest radiographs in AP and PA views, but it is generally accepted that the AP view is preferred in children due to their amenability.[15] In patients with a clear history of coin ingestion, chest radiographs including the entire length of the esophagus provide sufficient information to direct patient management as to whether a surgical approach is necessary.[1,11,14,16-17] For cases warranting a surgical approach, the most common intervention is endoscopic removal, which is essentially the treatment of choice.[3,16] Based on a search of HERDIN Plus, the ASEAN Citation Index (ACI), Western Pacific Region Index Medicus (WPRIM), Directory of Open Access Journals (DOAJ), and MEDLINE (PubMed and PubMed Central) using the search terms "foreign body," "foreign body ingestion," "coin ingestion," and "esophagoscopy," we found no English language studies that used regression analysis to predict the actual location of coin based on radiographic data.

This study aims to provide a guide to estimate the location of coins within the esophagus based on the pre-operative radiographic image among pediatric patients seen at East Avenue Medical Center by the Department of Otorhinolaryngology – Head and Neck Surgery (ORL-HNS) between January 2018 and December 2020.

METHODS

With East Avenue Medical Center Institutional Ethics Review Board approval (EAMC IERB 2023-32), this retrospective case series considered for inclusion all records of pediatric patients aged 13 years old and below who were admitted for coin ingestion and underwent emergency rigid esophagoscopy with successful foreign body extraction at the East Avenue Medical Center from January 1, 2018 to December 31, 2020. Records of those who did not undergo chest radiography in the institution (AP, PA, and/or lateral view/s in upright position) within 6 hours prior to surgery were excluded, as well as records of patients who had no, missing, or incompletely filled up charts, operative technique records, and chest radiograph official results.

The preoperative location of the coin, which was reported as vertebral level on chest radiographs, was obtained from the official results provided by the Radiology Department. Rigid esophagoscopies were performed by residents of the Department of ORL-HNS using the same set of 40-cm esophagoscope, suction and peanut forceps. The intraoperative location of the coin, which was reported as the distance of coin from the central maxillary incisors (CMI) in the operative technique, was recorded from the surgeons' intraoperative findings in each patient's medical record. The patient's age at the time of the procedure was recorded. The data were encoded using Microsoft Excel® for Mac version 16.68 (Microsoft Corporation, Redmond, WA USA).

Included patients were divided into age groups used based on diagnostic reference levels (DRL) age groups used by radiography systems to standardize radiation exposure based on patient sizes (full-term baby to adult).[15] Groupings were as follows: less than 3 years, 3-7 years and 8-12 years. Vertebral levels included were those with esophageal coin impaction.

Statistical analysis was performed using Stata version 15 (StataCorp LLC, College Station, TX, USA). A linear regression model was conducted using the number of included observations. The model shows that intraoperative location of the foreign body can be predicted if two predictors are provided: patient's age; and vertebral level of the coin on chest radiograph.

RESULTS

Records of a total of 112 pediatric patients diagnosed with coin ingestion who underwent emergency rigid esophagoscopy with successful foreign body extraction at the East Avenue Medical Center during the 3-year period were identified. Of these, records of 13 patients were excluded because the intraoperative location of coin was not documented on their operative technique records, leaving a total of 99 patient records for analysis. A linear regression model was conducted using 99 observations. The P-value was 0.0000 meaning that at least one of the predictors was associated with the outcome variable.

Of the 99 patients, there were 21 less than 3 years, 66 aged 3-7 years, and 11 aged 8-12 years. One patient who was 13 years old was included in the 8-12 years age group; thus there were 12 aged 8-13 years. Data gathered were only limited to vertebral levels C2, C4, C5, C6, C7, T1, T2, T3, T7, and T8 because none among the 99 patients had esophageal coin impaction at vertebral levels C1, C3, T4, T5, T6, T9, and T10 or the level of the esophageal hiatus.

The relationship between the vertebral level and the distance from the coin to the CMI in centimeters is shown in *Figure 1*. The slopes of the regression lines in the three age categories were similar to each other. This shows consistency for all age categories for the coin's predicted distance to the CMI as it passes through the esophagus from cervical vertebrae down to the thoracic vertebrae.

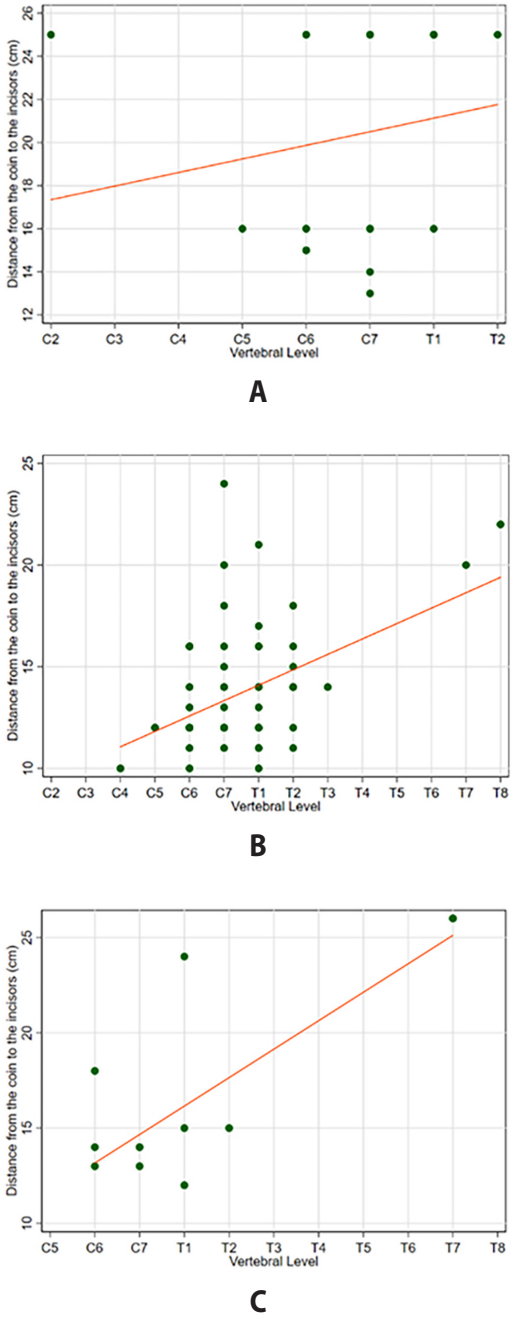

Figure 1. The relationship between vertebral level and distance from the coin to the incisors for patients **A.** less than 3 years old (*n* = 21); **B.** 3 to 7 years old (*n*= 66); and **C.** 8 to 13 years old (*n* = 12)

Table 1 shows the predicted distances based on the linear regression model. Proximal limit and distal limit are bounds of the 95% confidence interval estimate of the predicted distance. Predicted distances were also calculated for the categories not present in the observed data (*italicized*).

Table 1. Predicted Distances by Age Group and Vertebral Level

Age Group (in years)		Vertebral Level									
		C2	C4	C5	C6	C7	T1	T2	T3	T7	T8
less than 3	**Distance**	**10.0**	***10.0***	**11.6**	**13.1**	**13.9**	**13.3**	**14.9**	***14.1***	***22.9***	***22.1***
	Prox. Limit	4.0	*4.0*	8.4	11.4	12.3	11.6	12.6	*7.9*	*19.0*	*15.9*
	Dist. Limit	16.0	*16.3*	14.8	14.9	15.5	14.9	17.3	*20.3*	*26.9*	*28.3*
3 to 7	**Distance**	***9.9***	**10.0**	**11.5**	**13.0**	**13.8**	**13.2**	**14.8**	**14.0**	**22.9**	22.0
	Prox. Limit	*3.7*	4.0	8.5	11.7	12.5	11.9	12.9	8.0	19.2	16.0
	Dist. Limit	*16.0*	16.0	14.5	14.3	15.0	14.4	16.7	20.0	26.5	28.0
8 to 13	**Distance**	***11.6***	***11.7***	***13.2***	**14.7**	**15.5**	**14.9**	**16.6**	***15.7***	**24.7**	***23.7***
	Prox. Limit	*5.3*	*5.5*	*9.7*	12.7	13.5	13.5	14.0	*9.5*	21.1	*17.5*
	Dist. Limit	*18.0*	*18.0*	*16.7*	16.8	17.5	17.5	19.1	*22.0*	28.1	*30.0*

For patients less than 3 years old, a foreign body located at level C2 on chest radiograph is predicted to be located 10.00 cm (4.0 cm to 16.0 cm) from the CMI. A foreign body located at level C4 on chest radiograph is predicted to be located 10.0 cm (4.0 cm to 16.3 cm) from the CMI. A foreign body located at level C5 on chest radiograph is predicted to be located 11.6 cm (8.4 cm to 14.8 cm) from the CMI, and so on.

For patients aged 3 to 7 years old, a foreign body located at level C2 on chest radiograph is predicted to be located 9.9 cm (3.7 cm to 16.0 cm) from the CMI. A foreign body located at level C4 on chest radiograph is predicted to be located 10.0 cm (4.0 cm to 16.0 cm) from the CMI. A foreign body located at level C5 on chest radiograph is predicted to be located 11.5 cm (8.5 cm to 14.5 cm) from the CMI, and so on.

For patients aged 8 to 13 years old, a foreign body located at level C2 on chest radiograph is predicted to be located 11.6 cm (5.3 cm to 18.0 cm) from the CMI. A foreign body located at level C4 on chest radiograph is predicted to be located 11.7 cm (5.5 cm to 18.0 cm) from the CMI. A foreign body located at level C5 on chest radiograph is predicted to be located 13.2 cm (9.7 cm to 16.7 cm) from the CMI, and so on.

DISCUSSION

This study provides a novel guide that may serve as a tool for ENT surgeons. The guide predicts intraoperative location of coins in the esophagus based on preoperative radiographic imaging. Although coins are the most commonly ingested foreign bodies in children,[1,3-9] this study may also be applicable to cases of esophageal impaction of other radiopaque foreign bodies.

The age range of patients included in the study was 6 months to 13 years old. Estolano and Chua in 2015 reported that older pediatric patients have higher chances of spontaneous coin passage into their stomachs, with the highest percentage seen in the older age group of 14 – 16 years.[10] Their paper also provides additional evidence on why there are no patients who are 14 years old and above.[10]

Among patients less than 3 years old, none were admitted with coin impaction at vertebral levels T3 to T8. This may suggest that a coin, regardless of size, is more likely to be lodged proximally in the esophagus among patients less than 3 years old. It was also noted that among patients 8 to 13 years old, none had coin impaction at vertebral levels C2 to C5, which may suggest that a coin is likely to spontaneously pass through these levels for patients in this age group.

Chaudry and Bordoni in 2021 stated that foreign bodies typically lodge in one of the natural constrictions in the esophagus.[18] In most published literature, the most common site where foreign bodies become lodged is at the level of the cricopharyngeus or the post-cricoid area regardless of their age group.[5] The same is observed in the data we gathered, wherein patients aged 8 to 13 years old had their foreign body impacted at level C6, which corresponds to the upper esophageal sphincter (UES). The UES, also called the cricopharyngeus, was described by Jackson in 1907, as the narrowest among the four anatomic constrictions of the esophagus.[19] It is also the first constriction that will be encountered by esophageal foreign bodies;[19] hence, the likelihood of foreign bodies being impacted in that area is greatest.

The second esophageal constriction is at the level of T4 which corresponds to the arch of the aorta, the third constriction is at the level of T5 which corresponds to the crossing of the left bronchus in front of the esophagus, and the fourth constriction is at the level of T10 which corresponds to the diaphragm.[19]

Not all cases of coin ingestion warrant surgical intervention, as the possibility for a coin to pass spontaneously tends to increase in the following cases: children more than 5 years of age, ingestion of smaller sized coins (5 centavo and 25 centavo coins), and coins located at the distal third of the esophagus.[10] If the coin was noted to pass through the gastroesophageal junction, conservative outpatient management which includes watchful observation, serial imaging every 3-4 days, and resumption of regular diet is sufficient.[16,17] Patients and their caregivers should be advised to monitor stools for passage of the coin as it will usually pass spontaneously within 4 to 6 days.[16] For cases requiring surgical intervention, Fung *et al.* stated that rigid esophagoscopy is safe, effective, and generally the treatment of choice for foreign body ingestion.[11]

Based on two predictors, namely: patient's age, and vertebral level of the coin on chest radiograph, this study developed a tool ***(Table 1)*** which presents the estimated distance of the coin from the CMI, and the proximal and distal limit from the incisors wherein the coin is expected to be found. Predicting the location of coin or any foreign body prior to surgery may perhaps decrease the risk of intraoperative complications caused by repetitive insertion of rigid esophagoscope such as dental trauma, mucosal injury, or esophageal perforation. Other possible complications, although rare, are retroesophageal abscess, mediastinitis, and death.[10,20]

There are several limitations to our study. Although we understand the dynamic nature of ingested foreign bodies, our present study assumes limited coin movement from the time of radiographic imaging until the time it was retrieved (0 to 6 hours). The study is further constrained by limited operating room availability in a tertiary government hospital setting, where physicians compromise by obtaining serial radiographs every 6 hours to monitor the movement of the foreign body until an operating room becomes available. Future research could investigate datasets with more controlled and closer radiograph timings relative to surgery.

The linear regression model we used primarily estimates the average actual distance of the ingested coin, with its accuracy heavily dependent on the quality of the collected data. Currently, the study population was confined to patients treated at a single institution, which may limit the generalizability of the findings. Future research could enhance the robustness of these results by expanding the data volume and duration, incorporating additional variables to refine the estimates produced by the regression model, and including a more diverse participant pool from multiple hospitals across the country. This broader approach could enable more accurate predictions of the distance from the coin to the CMI across various age groups and vertebral levels.

We would like to think that our predictive model may shorten intraoperative time, lessen the patient's exposure to general anesthesia, avoid multiple insertion of rigid esophagoscope, and decrease the risk of complications such as dental trauma, mucosal injury or esophageal perforation, but these variables were not investigated in our present study. Future studies may consider analyzing these.

In conclusion, foreign body ingestion is a common reason for patients, especially children, to present in the emergency department and radiographs can confirm the ingestion of foreign body, identify its location, size, and shape, help exclude foreign body aspiration, and direct patient management as to whether a rigid esophagoscopy is necessary, but their use in predicting intraoperative location has not been previously elucidated. This study provides a novel guide that may serve as a tool for ENT surgeons to estimate intraoperative location of coin in the esophagus based on preoperative radiographic imaging.

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