Video Article

Handheld Metal Detector Screening for Metallic Foreign Body Ingestion in Children

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Abstract

Coins are the most common ingested metallic foreign bodies among children. The goal of this protocol is to assess the accuracy and feasibility of using a handheld metal detector to detect ingested metallic foreign bodies in children. We propose that by introducing handheld metal detector screening early in the triage process of children with high suspicion of metallic foreign body ingestion, the number of radiographs being ordered to localize the metallic foreign body can be reduced in this radio-sensitive population. The study protocol requires the screening of the participants for history of foreign body ingestion and exclusion of patients with respiratory distress or metallic implants. The patient changes to hospital gown and items that could contain metal like eyeglasses, earrings, pendants, and ornaments are removed. The patient is positioned in the center of the room away from other metallic interferences. The working status of the handheld metal detector is first confirmed by eliciting a positive audio-visual signal. Then the screening is done in an erect position with head in extension to expose the neck, from the level of the chin to the level of the hip joint, to cover the anatomical areas from neck to pelvis in a zig-zag manner both anteriorly and posteriorly. A positive audio-visual signal is carefully noted during the scanning for the presence of metallic foreign body. Relevant radiographs are ordered as per the area detected on the metal detector screening. The handheld metal detector was able to precisely identify all the coins among the ingested metallic foreign bodies in our study. The handheld metal detector could not consistently detect non-coin metallic foreign bodies. This protocol demonstrates the accuracy of handheld metal detector in the identification and localization of coins and coin like metallic foreign bodies.

Video Link

The video component of this article can be found at https://www.jove.com/video/58468/

Introduction

Foreign body ingestion is a widespread problem among children presenting to the pediatric emergency department because of the natural inquisitive nature of infants and children to explore objects by tasting and swallowing them[1,2]. Previous studies have reported that metallic objects constituted 85% of all foreign body ingestions in their cohort of patients[3,4]. The goal of this protocol is to assess the accuracy and feasibility of using a handheld metal detector to detect ingested metallic foreign bodies in children. We propose that by introducing the handheld metal detector screening protocol early in the triage process of children with high suspicion of metallic foreign body ingestion, the number of radiographs being ordered to localize the metallic foreign body can be reduced in this radio-sensitive population.

Handheld metal detector (HHMD) is an inexpensive, easily accessible adjunct that can help expedite the management of ingested metallic foreign bodies. Metal detector is a very low frequency device, which has a receiver and a transmitter that detects the change in its electromagnetic field caused by the presence of a metallic object in its vicinity[3]. If a metallic object is within the field, the electromagnetic field is disrupted and the sensor will set off an audio-visual alarm on the device[4]. The metal detector examination can be thoroughly performed in less than 2 minutes[5]. Hence, the HHMD screening can be introduced early in the triage process of children with high suspicion of metallic foreign body ingestion for topographical localization.

Coins are the most common swallowed metallic foreign bodies[1,4,6,7]. Due to the lack of sharp edges and general non-toxic nature, the majority of coin ingestions are managed conservatively. Other types of materials commonly ingested include magnets, button batteries, small toys, peanuts, jewelry, buttons, bones, seeds, and popcorn[8,9]. Impaction of foreign bodies most commonly occurs in the esophagus at three sites, namely upper esophageal sphincter, mid-esophagus at the level of aortic arch, and lower esophageal sphincter[10]. Metallic foreign bodies (MFBs) located in the esophagus may be asymptomatic in 40% of patients[11,12] and its prolonged impaction can lead to various complications like esophageal perforation, mediastinitis, tracheoesophageal fistula, tracheal stenosis, and aorto-esophageal fistulas[1,13,14,15]. Other locations of foreign body impaction include pylorus, duodenum, and ileo-caecal junction[10].

Performing radiographs of neck, chest, and abdomen to diagnose suspected foreign body ingestion is a widespread practice in the emergency departments[5]. Among all types of the ingested foreign bodies, only 10% are radio-opaque[10]. The radiological tests are time-consuming and have a risk of radiation exposure in children. Precise topographical localization of ingested metal objects is very crucial to guide therapy. The

introduction of HHMD screening early in the triage process can help mitigate extraneous ordering of radiographs by topographically localizing the ingested metallic foreign body.

This study evaluated the accuracy of HHMD to localize MFBs in a systematic topographic fashion and determined the effectiveness and feasibility of HHMD in the local Pediatric population. We also examined how well this radiation free screening tool was accepted by the patients and parents. Between May and July 2016, all the consecutive patients who presented to the pediatric emergency department with a history of foreign body ingestion were included in the study. Informed consent was obtained from the parent or legal guardian. Patients with alleged foreign body ingestion were systematically scanned using HHMD. The gold standard of care for identification and localization of ingested metallic foreign bodies is performing plain radiographs of the cervical area, thorax, and abdomen. To facilitate the conduct of the study, a standardized workflow was created (**Figure 1**). A log book specifically created based on the workflow was used to collect the initial data, which were subsequently transcribed to a spreadsheet (**Figure 2**). The data in the result section are depicted as the number of cases followed by percentages.

Protocol

The protocol follows the guidelines of Institutional Human Research Ethics committee. The central institutional review board provided the ethics approval for the study.

1. Participant Screening

1. Recruit patients who present to the pediatric emergency department with history of foreign body ingestion.
2. Exclude the patients who are in respiratory distress and has implanted devices like pace makers.

2. Prepare the Patient

1. Dress the patient in a hospital gown.
2. Remove all items that may contain metallic objects such as clothes, eye glasses, earrings, pendants, and ornaments prior to the examination to avoid interference with the HHMD screening.
3. Place the patient in the center of the room away from other potential metallic interferences.

3. Prepare the Examiner and Caregivers

1. Remove all metallic accessories such as jewelry and watch.
2. Request the caregiver to remove all metallic accessories such as jewelry and watch.

4. Metal Detector Screening

1. Use the HHMD (**Figure 1**) to conduct the screening.
2. Confirm the working status of the HHMD by eliciting a positive audio-visual signal by waving over a piece of metal.
3. Perform the HHMD scanning in a standing position for bigger children.
4. Perform the HHMD scanning in an erect position for infants by having the caregiver hold the patient appropriately.
5. Hold the hands of the patient up and away from the body.
6. Position the head of the patient in extension to expose the neck.
7. Scan from the level of the chin to the level of hip joint to cover the anatomical areas from neck to pelvis.
8. Perform the scan in a zig-zag manner across the body to ensure that every area has been scanned.
9. Scan both anteriorly and posteriorly as the thickness of patient must be taken into consideration.
10. Carefully note the positive audio-visual signal during the scanning for the presence of MFBs.

5. Perform the Relevant Radiograph

1. Order the relevant radiograph of the neck, chest, or abdomen, as per the area detected by the HHMD screening for the MFBs.
2. Proceed with all the X-ray views (neck, chest, and abdomen) if the MFB was not detected during HHMD screening and the clinical index of suspicion for foreign body ingestion is high.

6. Record the Test Results

1. Record the test results in the logbook (**Figure 2**) specifically created based on the workflow (**Figure 1**).
2. Correlate the positive audio-visual HHMD signal with the underlying bony landmark on the body, by palpating the following prominent bony landmarks - sternal notch, xiphisternum, pubic symphysis, and bilateral Iliac crest.
3. Record the landmark on the logbook's anatomical reference outline before proceeding with the X-ray examination.

Representative Results

The researchers recruited 36 patients for this observational study. These patients had presented to the pediatric emergency department with a history of foreign body ingestion. Among these, 28 patients had metallic foreign body ingestions (**Figure 3**). The remaining 8 patients had ingested non-metallic foreign bodies such as fish bones, satay stick, and plastic button. Coins were the most common type of foreign body ingested (**Table 1**), which comprised 30.5% of the patients. The other most common foreign bodies that were ingested included fish bone, toy parts, button battery, and metallic screws.

The HHMD examination was performed as per the standardized protocol for all the patients who had a strong history of MFB ingestion. This was followed by radiograph of a relevant area, if the MFB was detected during HHMD screening. The remaining patients, who had a strong history of foreign body ingestion and a negative HHMD screening, underwent radiographs of neck, chest, and abdomen. HHMD was able to precisely identify all the coins among the ingested MFBs in our study. The overall sensitivity of HHMD to detect coin was 100%. The specificity of HHMD to detect the coins was 100%. The positive and negative predictive value for the detection of coins using HHMD was 100% each.

Non-coin MFBs such as metallic screw, needle, and stapler pin which contributed to 13.7% of all ingestions, were not identified by the HHMD. However, these foreign bodies were not detected on the plain radiographs neither. This could be explained by the fact that either the foreign bodies were expelled, or the history of ingestion itself was questionable. For the patients who had ingested toys or toy parts, button battery, hair clip, metal ball, and metal screws (overall representing 30.2% of patients), the ability of the HHMD to detect the foreign bodies during the screening was similar to that by radiograph evaluation. All the metallic objects identified by the plain radiograph in this study were also accurately detected by the HHMD.

There were ingestions of a coke can flip top and a pendant (both composed of exclusive aluminium metal). Both these foreign bodies were accurately identified during the metal detector screening. However, these aluminum-containing foreign bodies were not visible on the plain radiographs, which were reviewed by both the pediatric emergency physicians and radiologists.

A post-procedure survey conducted among the HHMD users suggested that none of the members of the study team had difficulty explaining the protocol of HHMD use to the caregivers. The majority of the caregivers agreed to the fact that HHMD was able to detect the ingested metallic foreign body (77.7%). Further, 75% of the parents felt that by using HHMD, the need for X-ray examination for foreign body ingestion can be reduced. The main barriers to implementing HHMD in the workflow reported by the pediatric emergency physicians were patients' limitations as exclusion criteria, parents' choice, and clinician's preference.

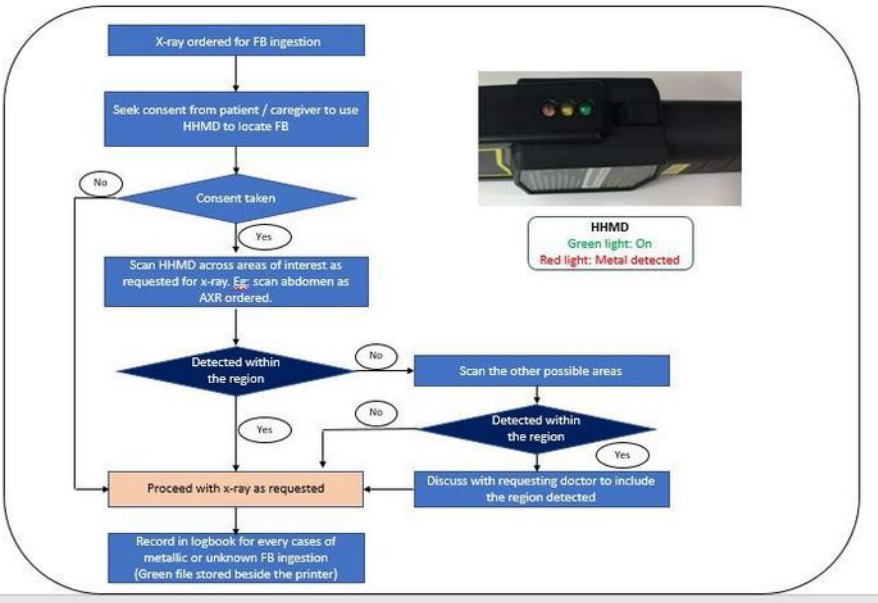

Figure 1: Workflow for the use of handheld metal detector. The handheld metal detector is depicted in the figure highlighting the visual signals. This flowchart has been modified from Hamzah *et al.* 2018[20]. Please click here to view a larger version of this figure.

Handheld Metal Detector (HMD) Usage Log (Please record all cases of foreign body ingestion for data collection purpose)									
Date of examination	Patient's Hospital number	Type of FB	HMD used – Y/N	If FB detected by HMD, mark the possible location **BEFORE** X ray	Circle the X ray **ordered**	Circle the X ray **performed**	FB seen on X ray images – Y/N	Comments / Remarks	Sign
16/5/2016	X12345A	Coin	Y		Neck Lat/ Chest AP&PA/ Abd AP&PA	Neck Lat/ Chest AP&PA/ Abd AP&PA	Y	Clinician agreed to do AXR only	abc
					Neck Lat/ Chest AP&PA/ Abd AP&PA	Neck Lat/ Chest AP&PA/ Abd AP&PA			
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Figure 2: Logbook used to record the patient details. The anatomical area of the audio-visual signal is marked on the figure. Also recorded are the details of the X-ray requested and X-ray performed. This figure has been modified from Hamzah *et al.* 2018[20]. Please click here to view a larger version of this figure.

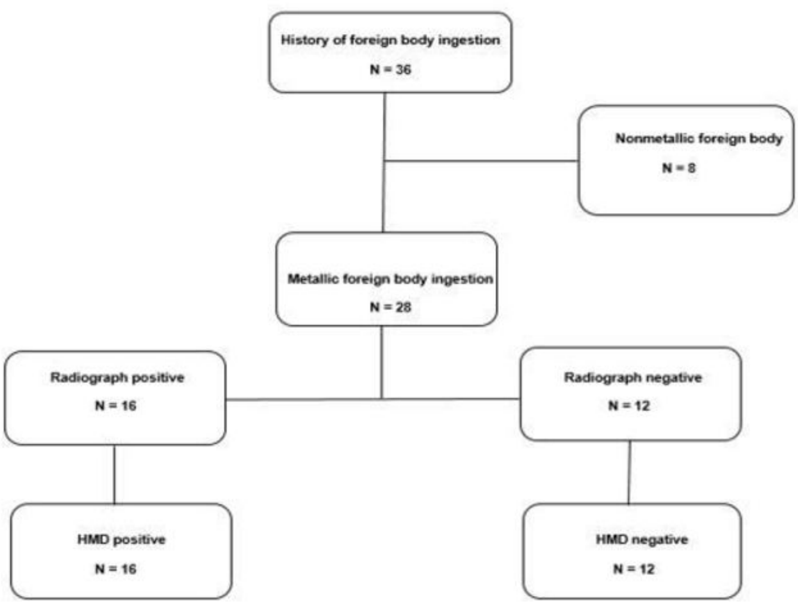

Figure 3: Patient recruitment flowchart. This flowchart has been adapted from Hamzah *et al.* 2018[20]. Please click here to view a larger version of this figure.

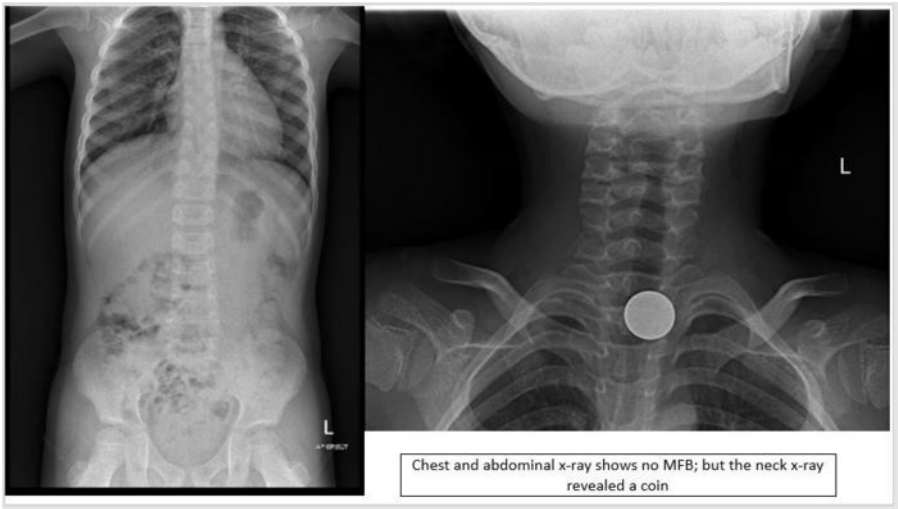

Figure 4: Missed MFB on routine chest-abdominal radiograph but detected on repeat neck radiograph. This figure has been adapted from Hamzah *et al.* 2018[20]. Please click here to view a larger version of this figure.

Type of FB	No of Cases (%)	Was HMD used?	Was HMD able to locate FB?	Was radiograph positive?
Coin[#]	11 (30.5%)	Yes	11 positives	11 positives
Fishbone[%]	6 (16.6%)	No	Not applicable	4 positives, 2 negatives
Toys or toy parts[#]	5 (13.8%)	Yes	2 positives, 3 negatives	2 positives, 3 negatives
Battery[#]	3 (8.3%)	Yes	1 positive, 2 negatives	1 positive, 2 negatives
Screws[#]	3 (8.3%)	Yes	3 negatives	3 negatives
Hairclip[#]	1 (2.7%)	Yes	1 positive	1 positive
Needle[#]	1 (2.7%)	Yes	1 negative	1 negative
Coke can flip top[#*]	1 (2.7%)	Yes	1positive	1 negative
Satay stick[%]	1 (2.7%)	No	Not applicable	1 positive
Metal object (pendant)[#*]	1 (2.7%)	Yes	1 positive	1 negative
Metal ball[#]	1 (2.7%)	Yes	1 positive	1 positive
Plastic Button[%]	1 (2.7%)	No	Not applicable	1 negative
Stapler pin[#]	1 (2.7%)	Yes	1 negative	1 negative
- # metallic foreign bodies				
- * aluminium objects				
- [%] non-metallic foreign bodies				

Table 1: Types of foreign bodies ingested. This table has been modified from Hamzah *et al.* 2018[20].

Discussion

Metallic foreign body ingestion in children is a common problem and in the majority of patients, this is managed conservatively[7,16]. Single or repeated radiographs can expose the radio-sensitive pediatric population to unwanted radiation risk while attempting to localize the ingested metallic foreign body. Several studies have described the use of metal detectors in MFB ingestion in children, with sensitivity more than 96% and specificity greater than 80%[1,7,17,18,19]. Metal detector has an inherent oscillating circuit which is altered in the presence of a metallic device causing a disturbance in its electro-magnetic field[1]. This results in the generation of the sound alarm and visual signal from an audio-piezo material in the device[20,21]. Metal detectors can detect both non-magnetic and magnetic materials such as iron, silver, lead, aluminum, copper, and brass[5].

As reported in the previous studies, coins were the most common MFBs detected in our study[22,23]. In our study, all the swallowed metallic coins were identified by the metal detector as accurately as that done by the plain radiograph. Ingested coins have a propensity to get impacted in the thoracic inlet[24] and hence limited radiographs of the chest may overlook the metallic foreign body. This was evident in one patient prior to the

initiation of this study (**Figure 4**). Previous studies have shown that a short-term training was adequate to accurately perform handheld metal detector examination and the difference between experienced and inexperienced examiners is not significant statistically[3,4,6,22]. Hence a "see one, do one, and teach one" approach can help achieve proficiency in the metal detector examination. The metal detector examination can be thoroughly performed in less than 2 minutes[5]. Hence, the handheld metal detector screening can be introduced early in the triage process of children with high suspicion of metallic foreign body ingestion. This can help to limit the number of radiographs being ordered for the patient to localize the metallic foreign body.

In patients with an unreliable history of metallic foreign body ingestion, the results of handheld metal detector screening must be interpreted with caution. A negative metal detector screening does not negate the need for radiograph evaluation. The authors recommend the use of further detailed diagnostic imaging if a foreign body other than coin was ingested or the patient is overtly symptomatic, in order to prevent missing a foreign body. For those children presenting to the emergency department with outside radiographs, already done to localize the metallic foreign body, metal detector screening can help minimize the need for repeat radiographs.

Repeat radiographs are often necessary for localization of the foreign body prior to the definitive procedure for removal of the foreign body. They can expose the patients to additional radiation and add on to the treatment expense. Use of HHMD screening can help preclude repeated radiographs and concurrent cost by providing useful preoperative information[6]. HHMD can be used to perform repeat examinations and accurately localize the metallic foreign body while the patient is awaiting endoscopic removal, because sometimes several hours may lapse before the definitive treatment is performed[4,6]. Handheld metal detector is a very valuable tool in the follow-up of the course and passage of ingested metallic foreign bodies, which are identified positive during the initial presentation to the emergency department[3]. The use of metal detector screening may effectively replace repeat radiography for the follow-up of metallic foreign body expulsion from the body[6]. The use of HHMD re-screening can also negate the practice of routinely examining the stools for foreign bodies, which is messy and unreliable and may lead to unnecessary anxiety in the caregivers, if there is a failure to detect the foreign body[1].

There were two aluminum foreign bodies in our study that were missed on plain radiograph but detected on metal detector screening. The invisibility of aluminum objects in plain radiographs, due to its relative radiolucency[22], has been previously documented in literature. Aluminum objects can be very difficult to detect even using a thin barium swallow technique[2]. X-ray absorption of a metal is determined based on the fraction of the third power of atomic number and energy of the X-ray beam. In most of the emergency department settings, energy of the X-ray beam is constant. Aluminum has an atomic number of only 13 and hence it remains relatively radiolucent. Metal detectors are more sensitive than plain radiographs in the detection and localization of aluminum foreign bodies[20,21,22].

The metal detector screening is limited by the fact that even though it might accurately identify the presence of a coin in the neck, the metal detector cannot differentiate between airway or upper gastrointestinal tract location of the MFB. This could have serious implications in the retrieval of foreign body. HHMD examination is unreliable for very small metallic foreign body ingestion like metallic battery, screws, hairpin, and stapler pin[25]. Profound obesity is a relative contraindication for metal detector examination due to the relative increased distance from metallic objects to the scanner[1].

The critical step in the HHMD screening protocol is to remove all items, which could contain metallic objects such as clothes, eyeglasses, earrings, pendants, and ornaments prior to the examination to avoid interference with the HHMD screening. Also, the patient must be placed in the center of the room at least 1-m away from other potential metallic interferences. It is also of paramount importance for the examiners and caregivers to remove all metallic accessories like jewelry and watch. Prior to the initiation of the HHMD screening, confirm the working status of the handheld metal detector, by eliciting a positive audio-visual signal, by waving over a piece of metal. In case of a negative signal, change the batteries and re-attempt. If the signal persists to be negative, an alternative HHMD in working condition should be used. Ideally, the HHMD scanning should be done in a standing position, with hands of the patient up and away from the body. This technique can be modified in infants by requesting the caregivers to hold the patient in the erect position. The head of the patient must be in extension to expose the neck. In order to avoid missing an MFB during the screen, ensure that the scan is done from the level of the chin to the level of the hip joint in a zig-zag manner across the body, both anteriorly and posteriorly.

In conclusion, our study demonstrates that HHMD can be safely and reliably used as a screening tool in the process of detecting ingested coins and coin-like MFBs. The plain radiograph still remains the gold standard to detect sharp metallic objects as well as button batteries, the management of which is very time-sensitive. In order to confirm the expulsion of the metallic foreign body during the follow-up visit, HHMD can be used as an effective screening tool. For the detection of radiolucent foreign bodies such as those composed of pure aluminum, HHMD is more sensitive than the conventional X-ray examination. The HHMD being a pain free tool with prominent audio-visual signals can keep young children happy and engaged during the examination process[21]. A metal detector can also be a valuable tool in an office-based practice to help detect metallic foreign bodies prior to referring the patient to an emergency department.

Disclosures

The authors have nothing to disclose.

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