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The utility of a handheld metal detector in detection and localization of pediatric metallic foreign body ingestion

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ABSTRACT

Objective: To test the ability of a handheld metal detector (HHMD) to identify the presence and location of ingested metallic foreign bodies (MFBs) in children.
Methods: Prospective case series enrolling children suspected of metallic foreign body ingestion presenting to the Emergency Department. Thirty-eight children were enrolled and the HHMD was used to detect the presence and location of a MFB. Results were compared to standard radiographic studies.
Results: Thirty-seven of the 38 ingested foreign bodies were MFBs. Of the 37 MFBs, the HHMD positively identified 33, and 4 were missed by HHMD but identified on radiography. When positive, the location indicated by HHMD correlated 100% with radiograph. There were 33 true positives, 0 false positives, 4 false negatives, and 1 true negative. This resulted in a sensitivity of 89% (95% CI of 75%–96%) and specificity of 100% (95% CI of 2.5%–100%).
Conclusion: Our study demonstrates the accuracy of HHMD in the identification and localization of metallic foreign bodies. We propose an emergency room foreign body protocol that uses HHMD as an early screening tool in triage in order to expedite the process of obtaining Otolaryngology consultation and potentially shorten the wait time to the operating room or discharge. In instances were outside films are previously performed, HHMD use may be able to minimize the overall radiation exposure to children by obviating the need for repeat radiographs.
As the sensitivity is not 100%, a negative HHMD screening does not negate the need for a standard radiograph in order to avoid missed MFBs. HHMD is best suited for detection of coins, which accounts for the majority of the MFB ingestions, and may not be suitable for all metallic objects since the amount of metal may decrease its sensitivity.

1. Introduction

Ingestion of foreign bodies is a common occurrence in children, and up to 85% are reported to be metallic foreign bodies (MFBs) [1]. The most frequently swallowed MFBs are coins [2], but children may swallow many other types of MFBs including pins, screws, magnets, button batteries, nails, and others. In a home based survey, up to 4% of the parents reported that their children had swallowed a coin at some point in their life [3].

As in most diagnoses in medicine, the most important piece of information is the parental history of a witnessed ingestion, as patients can be asymptomatic and remain so for over 5 days in about 70% of cases of an ingested esophageal coin [4]. Although most esophageal MFBs can be managed in a straightforward manner, a delay in diagnosis may lead to increased risk of serious morbidities [5]. The incidence of esophageal perforation associated with ingested blunt foreign bodies is approximately 1% [6], but can be higher with impacted foreign bodies ranging from 2 to 15% [7]. Other complications include mediastinitis [8], false or true esophageal diverticula, tracheoesophageal fistulas, tracheal stenosis [9], aortoesophageal fistulas, and death [10].

The current standard of care for the identification and localization of swallowed MFBs is plain films of the neck, chest and/or abdomen. If positive, then Otolaryngologists are consulted for endoscopic removal, typically in tertiary centers. Often plain films are first obtained at ambulatory clinics or community hospitals prior to children being referred to a tertiary pediatric Emergency

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Department. Depending on the length of the transfer process, repeat films are often necessary for confirmation and localization prior to surgery. Exposing children to repeated bouts of radiation is becoming less favorable, as the medical community has become more aware of the higher lifetime risk of developing secondary malignancies in children exposed to radiation at a young age [11].

A handheld metal detector (HHMD) is an inexpensive and readily available adjunct in the management of MFBs that minimizes the risk of ionizing radiation. A HHMD operates by generating a low-intensity magnetic field that passes from one end of the detector to the other. If a metal object is within the field, the magnetic field is disrupted and the sensor will detect the change and set off an alarm by emitting an audible beep, a red LED light flash, and tactile vibration. A HHMD does not generate any ionizing radiation.

The aim of this study is to evaluate the ability of a HHMD to identify the presence and location of an ingested MFB. Our hypothesis is that a HHMD may accurately detect the presence and location of a MFB. We propose to integrate the HHMD into a formalized emergency department foreign body pathway in order to minimize wait time, streamline evaluation, reduce cost, and decrease the use of ionizing radiation.

2. Materials and methods

This is a prospective study enrolling children between the age of 1 and 18 with suspected MFB ingestion who presented to the Emergency Department at Rady Children's Hospital San Diego from March 1, 2014 to February 29, 2016. The study obtained research approval from the University of California San Diego Institutional Review Board committee. Inclusion criteria was any child presenting to the Emergency Department with a suspected MFB ingestion who was clinically stable with parents or guardians present to give consent. Exclusion criteria were subjects with respiratory distress who required immediate resuscitation and urgent operating room intervention, and subjects with implanted devices who may be sensitive to an electromagnetic field such as pace makers, ICDs or spinal cord stimulators. After the initial Otolaryngology consultation in the Emergency Department the patient and family were recruited into the study with informed consent and a HIPAA waiver.

After the initial history and physical examination, the patients underwent HHMD scanning. When using the HHMD, any metal in the immediate scanning area were removed such as jewelry, eyeglasses, buttons, belt buckles, zippers, or objects around the patient such as the hospital bed metal railing, and surrounding medical equipment. The patients were dressed in a hospital gown and stood if age appropriate or held on the lap by their parent or guardian away from any surrounding metallic objects. The patients were positioned with their hands up and away from their body, and their neck in extension exposing their entire anterior neck (see Fig. 1). The HHMD was then verified to be working by waving it over a piece of metal, and then waved over the front of the patient starting over the nose and down to the pubic symphysis and then again behind the patient. The collected information was then recorded as: presence of metallic object (yes or no), and the location of the metallic object was drawn on a standard body diagram with categorized locations as: neck – above the sternal notch, chest – between sternal notch and xyphoid process, and abdomen – below the xyphoid process. Then standard plain films with both anteroposterior and lateral views were obtained as the current accepted standard of care. The plain films then served as the criterion standard for comparison of the results obtained with the HHMD.

Patients with present MFBs in the neck or chest were then taken to the OR for removal and the type of MFB was recorded. Children with MFBs that passed the gastroesophageal junction on plain film were reassured and discharged home with instructions to return if abdominal pain, vomiting or bloody stools occur since it has been demonstrated that most ingested foreign bodies below the esophagus can be spontaneously passed without complication [12].

The HHMD used for this study was the Garrett Super-scanner® V (Garrett Electronics, Inc. Garland, Texas). The dimensions were 42 cm long, 8.3 cm wide, 4.13 cm thick, and weighed 500 g. The HHMD is not FDA approved for this specific medical purpose; however, the use of HHMD for security purposes is ubiquitous, and is currently being used in many US and International airport security checkpoints. Studies have shown that because of its non-ionizing properties, the very low magnetic field generated in a metal detector will not cause harm to even pregnant women and their fetuses with routine and/or repeated scanning [13,14]. Therefore, the use of the device in clinical care does not pose any significant risk to subjects. The electromagnetic fields produced by Garrett products are similar to those encountered in the daily environment and meet U.S. and International standards for electromagnetic emissions [15]. The scanner was used according to manufacturer instructions.

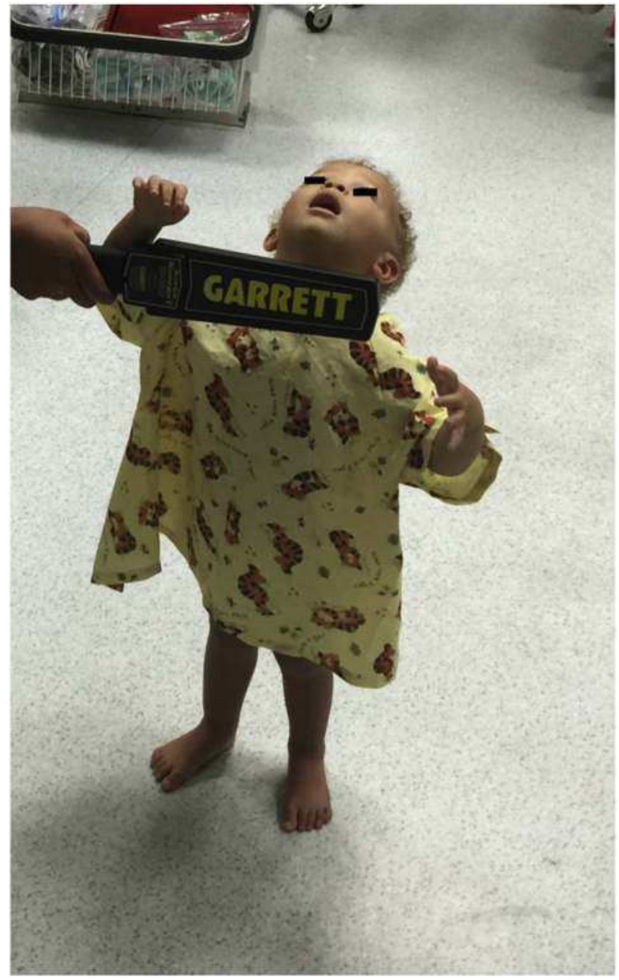

Fig. 1. Demonstration of wanding technique. Patient positioned in center of room away from any surrounding metallic objects. Patient placed in hospital gown with no zippers or buttons. During examination patient extends head to expose the neck, and hold hands up and away from the body. The HHMD is slowly passed from the chin to the pubic symphysis in front and in back of the patient.

A standard diagnostic test valuation was performed to calculate the sensitivity and specificity.

3. Results

A total of 38 patients were recruited over the course of the 2-year study. All patients underwent evaluation with both the HHMD and a plain film radiographic study. Patient's ages ranged from 7 to 79 months (average 27 months; median 22 months); with 19 males and 19 females. Thirty-seven of the 38 ingested foreign bodies were metallic and the non-metallic foreign body was a sunflower seed. The ingested MFBs included: 18 pennies, 5 nickels, 2 dimes, 8 quarters, 1 spring, 1 ear bud mesh, and 2 that were unknown (but appeared to be coins on radiograph) as they were not removed and allowed to pass. Thirty-one objects were located in the neck and four in the chest, all of which were removed endoscopically. The two remaining MFBs were in the stomach and those patients were discharged home to allow for spontaneous passage. Of the 37 MFBs, the HHMD positively identified 33, and 4 were missed but identified on radiography, including 1 penny in the neck, 1 dime in the chest, 1 ear bud mesh in the neck, and 1 unknown in the stomach (see Figs. 2 and 3). When identified by the HHMD, there was no discrepancy in location when compared to x-rays, resulting in a 100% accuracy of location.

There were 33 true positives, 0 false positives, 4 false negatives, and 1 true negative. This resulted in a sensitivity of 89% (95% CI of 75%–96%), specificity of 100% (95% CI of 2.5%–100%).

In all patients taken to the operative suite, the foreign body was removed without any perioperative or postoperative complications. No re-visits or readmissions were reported for patients discharged from the emergency room.

4. Discussion

The current recommendation for children with a history of suspected coin ingestions is to undergo antero-posterior and lateral neck and chest radiographs to assess for presence and location of a coin and to rule out any other associated complications [16]. Since the first publication using a metal detector for localization of swallowed coins in 1980 [17], many studies evaluating the efficacy of HHMD have been published mostly in the Emergency Medicine and Pediatrics literature, demonstrating its accuracy. However, the practice of using a HHMD as a screening tool in the emergency rooms and by pediatric Otolaryngologists in United States is not widespread. A systematic review and meta-analysis was done by Lee et al. [18] in 2005 that reviewed 11 prospective studies, and found no evidence of heterogeneity for sensitivity (x^2 = 8.0, p = 0.43) or specificity (x^2 = 0, p = 1.0). The overall sensitivity of the HHMD at detecting the presence of coins was 99.4% (95% confidence interval (CI) 98.0–99.9%) and accuracy at localization was 99.8% (98.5–100.0%). The overall specificity of the HHMD was 100% (76.8–100%). In this study, the sensitivity was 89% for all MFBs and 94% for coins, slightly lower than some of the previously published results. When analyzing the patients with a false negative result, there were no consistent variables between them. The age ranged from 10 to 78 months, 2 MFBs were located in the neck with 1 in the chest and 1 in the stomach. One penny, 1 dime, 1 ear bud mesh, and one unknown MFB were missed. In the case of the missed penny, the coin had been in the esophagus for several days, and there was a large amount of granulation tissue surrounding the coin at endoscopy. In the cases of the dime and the ear bud mesh, the smaller amount of metal may be below the detection threshold of the particular HHMD used in this study.

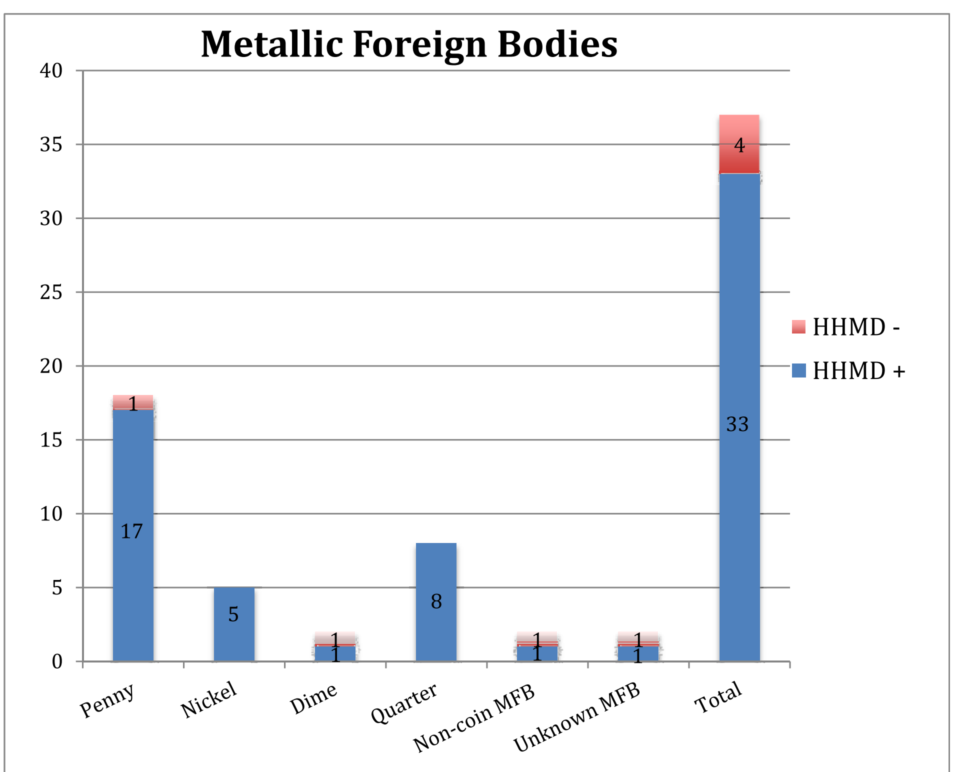

Fig. 2. Types of ingested metallic foreign bodies and HHMD ability to detect. 4 objects were missed (highlighted in red, HHMD-); 1 penny, 1 dime, 1 non-coin MFB, and 1 unknown MFB. 33 MFB were correctly identified (HHMD+) with the HHMD. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

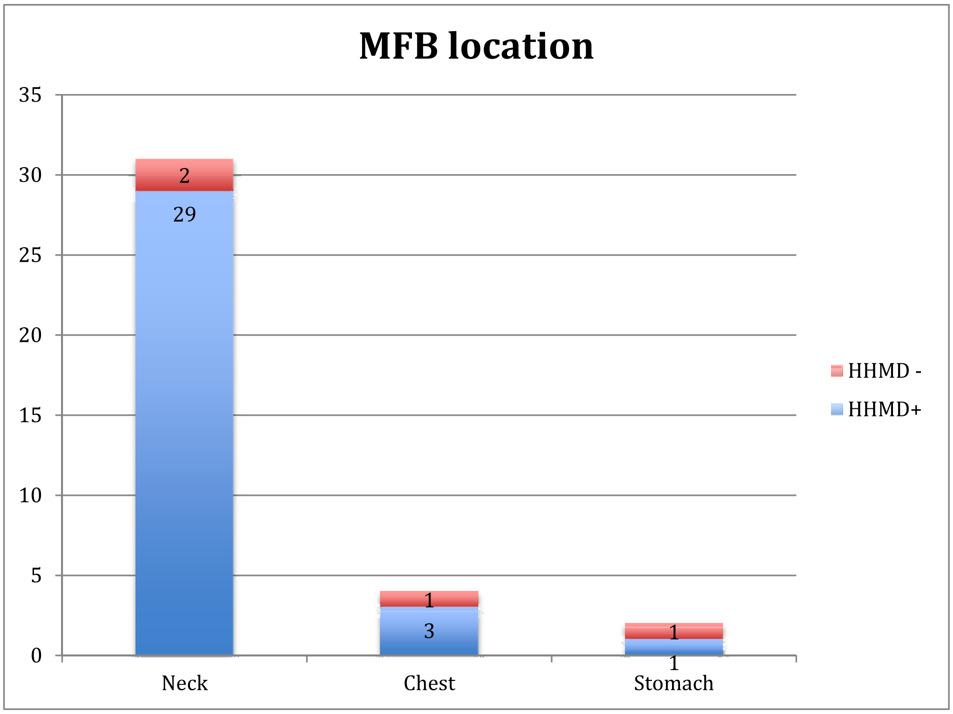

Fig. 3. MFB locations. The location of the MFB as identified by the criterion standard plain film. Four MFBs were missed, 2 in the neck, 1 in the chest, and 1 in the stomach.

The reliability of the HHMD in detecting non-coin MFBs may be quite variable. Schalamon et al. [19] reported 8 of 15 non-coin MFBs were missed, including 2 button batteries and a needle. Ros and Cetta [20] reported failure to detect several objects, including a safety pin, paper clip, tack, watch battery, AA battery, and iron pill. In our study there were 2 non-coin MFBs, 1 being a spring that was successfully identified by the HHMD, and the other an ear bud mesh that was seen on x-ray but not HHMD. There were also 2 MFBs that had the appearance of a coin on x-ray but were unconfirmed by endoscopy since patients were discharged home and the objects were allowed to pass without removal. One of those was identified by the HHMD and the other was not.

In the literature, 16 false positives for an ingested MFB have been reported in 3 studies combined [1,21,22]. Eight of those false positives were eliminated though when a surrounding metallic object was identified, removed, and the patient was rescanned. In this study there were no false positives.

In our study residents, fellows, and attendings performed the HHMD evaluation and there was some thought that maybe this heterogeneity was responsible for 4 MFBs being missed. However, the Seikel et al. study [22] demonstrated that no training is needed in order to be able to use the HHMD accurately. They compared the results of experienced investigators to inexperienced operators who had been instructed on HHMD use for less than 1 min. Experienced investigators had a positive predictive value of 90.9% and a negative predictive value of 100%. The difference between experienced and inexperienced investigators was not statistically significant.

Based on the results of this study, a patient flow diagram has been designed to manage patients with suspected MFBs, with the goal of decreasing triage time and radiation exposure (see Fig. 4). In a patient who presents with a suspected MFB ingestion, the first and most important detail to obtain is whether or not there is any possibility that the object is a button battery. If there is any possibility, then the HHMD maybe used as early as triage to localize the object and an emergency protocol should be activated at the same time with STAT plain films, ENT consultation and call to the operating room for possible endoscopic removal. In other non-emergent situations, there are two major roles for the HHMD; to replace the necessity for a repeat x-ray prior to endoscopy when a previous film has confirmed the presence of a MFB and to be used as an early screening tool for all patients with ingested MFB prior to x-ray.

Once a non-button battery MFB is identified, depending on the symptoms of the child, the NPO status, and operating room availability, timing from identification to endoscopy may be quite variable. Twenty-five to 30% of esophageal coins in children may pass spontaneously without complication especially if the children are older and the coin is in the distal esophagus [23], however most coins are ingested by younger children and are predominantly lodged at the cricopharyngeus [24]. Up to 40% of coins have reported to pass into the stomach within 1–5 h [16], therefore, when there is a delay of longer than 4 h between initial radiograph and endoscopy, a repeat film is typically obtained to confirm location of the coin prior to endoscopy. Delays are also common when children are initially evaluated with radiographic studies in community clinics or hospitals and subsequently referred to tertiary centers for operative management. The use of the HHMD may effectively replace the repeat radiographic study with 100% specificity and 100% accuracy as supported by the current study and demonstrated by Younger and Darrow previously [25].

For those patients without a previous study, the HHMD may be used early in the triage process for children with a high suspicion of coin or MFB ingestion. If the HHMD is positive with localization in the neck or chest, pediatric otolaryngologist on call may be contacted immediately with the anticipated need for esophagoscopy to expedite care. The plain film maybe obtained prior to the arrival of the consultant to evaluate the child. If the HHMD indicates location in the stomach, then an x-ray may be used for confirmation prior to discharge home. In case of a negative HHMD exam, a plain film should be obtained prior to discharge to rule out a missed MFB.

The limitation of our study is that the sample size is relatively small. Providers with various levels of training including residents

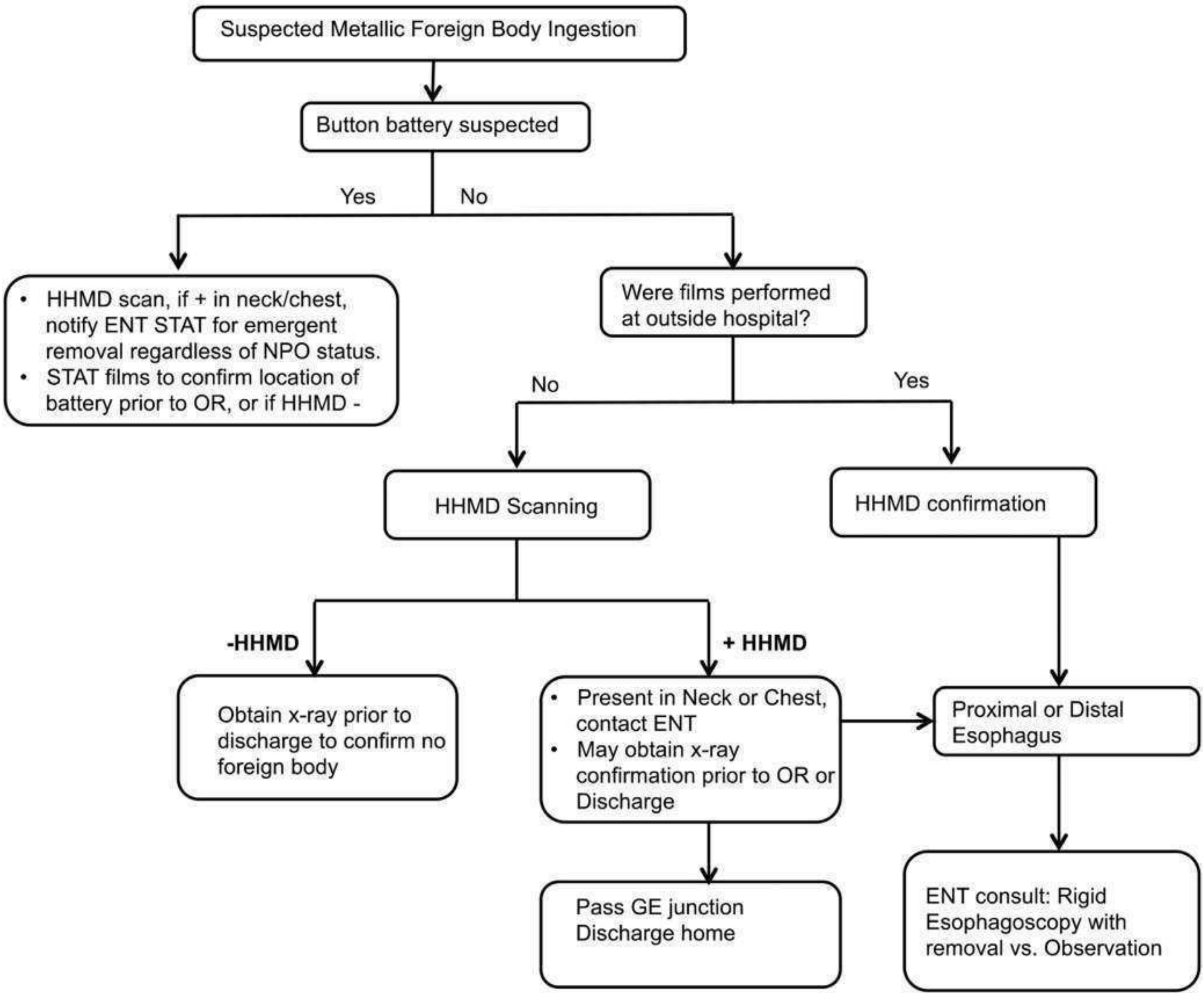

Fig. 4. Flow diagram demonstrating proposed HHMD use in the triage process.

and fellows performed the protocol. However, this may reflect more accurately the real world situation when the HHMD may be operated by non-tertiary emergency room personnel and inexperienced users.

5. Conclusion

Ingestions of MFB are common occurrences in the pediatric Emergency Department. Our current study protocol was able to demonstrate the accuracy of the HHMD in the identification and localization of metallic foreign bodies. Previous studies have demonstrated that when compared to the standard plain radiograph, HHMD has high sensitivity and specificity especially for metallic coins. When the history is uncertain as to the type of foreign body ingested (i.e. non-metallic), the result of the screening needs to be interpreted with caution. A negative HHMD screening does not negate the need for a radiographic foreign body series in order to avoid missed MFBs. HHMD is still best suited for detection of coins that account for the majority of the MFBs ingestions, and may not be suitable for all metallic objects since the amount of metal may decrease its sensitivity.

We propose an emergency room foreign body protocol that uses the HHMD as a screening tool early in the triage process, instead of using it as confirmation. This should expedite the process of obtaining Otolaryngology consultation early and potentially shorten the wait time to the operating room. In instances where outside films previously performed, the HHMD may be able to minimize the overall radiation exposure to these children by obviating the need for repeat radiographs.

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