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DIAGNOSTIC CODING OF PHYSICAL ABUSE AMONG PATIENTS EVALUATED BY A MULTIDISCIPLINARY CHILD PROTECTION TEAM IN A PEDIATRIC LEVEL I TRAUMA CENTER

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DIAGNOSTIC CODING OF PHYSICAL ABUSE AMONG PATIENTS EVALUATED BY
A MULTIDISCIPLINARY CHILD PROTECTION TEAM IN A PEDIATRIC LEVEL I
TRAUMA CENTER

by

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2019

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TRAUMA CENTER

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TRAUMA CENTER

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Child abuse is a substantial public health problem. Numerous studies have used hospital discharge data coded using the International Classification of Diseases, 9th and 10th Editions, Clinical Modification (ICD-9 and ICD-10) to identify cases of physical abuse seen in hospitals. Published studies on the sensitivity and specificity of ICD coding for physical child abuse are limited using ICD-9, and non-existent with ICD-10. This study examined the accuracy of ICD coding for physical child abuse, among patients less than 18 years of age, who were evaluated due to concern for physical abuse by a Multidisciplinary Child Protection Team (MCPT) during 2012-2013 (n=391, using ICD-9) and 2016-2017 (n=303, using ICD-10) in a Pediatric Level I Trauma Center in Texas. Sensitivity, specificity, and positive and negative predictive values were calculated for ICD coding using the abuse determination of the MCPT as the gold standard. In 2012-2013, sensitivity of ICD-9 coding was only 21.7% (95% CI 15.2-29.3%) and specificity was 98.4% (95% CI 95.9-99.6%). In 2016-2017, sensitivity of ICD-10 coding was 31.3% (95% CI 24.7-38.6%) and specificity was 85.1% (95% CI 77.5-90.9%). False positive ICD-10 coding primarily involved the code for suspected child physical abuse (T76.12), which

had no analogue under ICD-9. Few patients who were evaluated for possible physical abuse received the expected supplementary code for examination for possible physical abuse (19% in 2012-2013 and 4% in 2016-2017). Sensitivity of ICD-coding for physical abuse was very low. Researchers should be cautious in using ICD-coded datasets alone for physical child abuse surveillance.

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BACKGROUND

Literature Review

Child maltreatment definitions

Legal definitions of child abuse and neglect vary by jurisdiction, but the umbrella term *child maltreatment* is often used to encompass any form of abuse (physical, sexual, or psychological) or neglect of children which causes risk of serious harm to the child (U.S. Department of Health & Human Services [DHHS], 2018). In 2008, the Centers for Disease Control and Prevention published a set of uniform definitions for public health surveillance in child maltreatment, along with recommendations for data collection. Under these recommendations, broad categories of child maltreatment include child abuse (such as physical abuse, sexual abuse, and psychological abuse) and child neglect (such as failing to provide for a child's basic needs or failing to adequately supervise a child) (Leeb, Paulozzi, Melanson, Simon, & Arias, 2008). Within the category of child abuse, Leeb and colleagues further define physical abuse as “the intentional use of physical force against a child that results in, or has the potential to result in, physical injury.” Physical injuries that occur during the commission of sexual abuse are considered sexual abuse, rather than physical abuse (Leeb et al., 2008).

Evaluating patients for child abuse in hospital settings

When considering all types of maltreatment, medical personnel are the fourth largest group of people who report suspected child maltreatment to child protection authorities (DHHS, 2018), and hospitals have a prominent role in identification of serious physical abuse which causes about 44% of abuse-related fatalities annually (DHHS, 2018). Evidence

suggests that hospitals where staff have specialized experience and training in pediatric trauma are more likely to detect physical child abuse. A study by Bogumil, Demeter, Imagawa, Upperman and Burke (2017) estimated the prevalence ratios (adjusted by Injury Severity Score) for reported physical child abuse at different hospital types between 2007 and 2014. They found that the reported prevalence of physical child abuse was 1.81 (95% CI 1.73-1.90) times higher at dedicated Pediatric Trauma Centers that were verified by the American College of Surgeons (ACS), compared to hospitals not verified by ACS. One advantage for many ACS-verified Trauma Centers is the availability of a Multidisciplinary Child Protection Team (MCPT) for evaluation of patients for possible abuse. The determinations of such teams are often considered the gold standard for diagnosis of child abuse in the hospital setting, and larger hospitals may maintain a registry of these determinations (Berger, Parks, Fromkin, Rubin, & Pecora, 2013). The composition of different professions on these MCPTs is not uniform, not all hospitals have access to such a team, and there is no single repository for the determinations of these teams across multiple hospitals. In the absence of a MCPT, some hospital-based epidemiologic studies have used the determination of a single pediatrician with specialized knowledge of child abuse diagnosis as the gold standard (Hooft et al., 2015). However, this approach is likely more prone to bias on the part of individual clinicians, even when those clinicians are highly trained and experienced in child abuse evaluations (Lindberg, Lindsell & Shapiro, 2008; Lane, Rubin, Montheith & Christian, 2002; Wood et al., 2010) Determinations of the likelihood of abuse made by MCPTs are complex and ultimately rely on professional

judgements. While not a comprehensive list, Appendix A highlights several indicators routinely considered by MCPTs in making abuse determinations.

International Classification of Diseases

The World Health Organization's International Classification of Diseases (ICD) provide a global means of reporting and studying causes of mortality (Jetté et al., 2010). Many countries also use customized versions of ICD coding systems for reporting morbidity data. The International Classification of Diseases, 9th Edition, Clinical Modification (ICD-9-CM) was used in the United States from the late 1970's until October 2015, when hospitals nationwide transitioned to the International Classification of Diseases, 10th Edition, Clinical Modification (ICD-10-CM) (O'Malley et al., 2005; Andrews, 2015). In practice and in the remainder of this paper, the "CM" designation is often omitted – it is implied in any research focused on clinical rather than mortality data. ICD-coded data for an encounter in the hospital may include diagnosis codes for that visit, as well as V-codes for "Supplementary Classification of Factors Influencing Health Status and Contact with Health Services" and E-codes to specify the external cause of injuries (O'Malley et al., 2005; Centers for Disease Control & Prevention [CDC], National Center for Health Statistics, 2017).

ICD coding of patients seen in hospitals is usually performed by trained medical coders, based on post-discharge review of the patient medical record. Regardless of medical condition, how well the results of this coding process reflect the clinicians' observed diagnosis is affected by many factors such as training and reference materials available to the coders, coder experience, legibility and clarity of writing in the medical record, variation in terminology used, completeness of the medical record, and the ever-changing state of

medical knowledge (O'Malley et al., 2005). The general accuracy of ICD coding is also related to the validity of the diagnosis itself and may be subject to bias on the part of clinicians, as well as limits on time, communication and information provided by the patient (O'Malley et al., 2005).

ICD coding for child abuse poses additional layers of complexity, and potential for error beyond that known to exist for coding of other conditions (Scott, Tonmyr, Fraser, Walker, & McKenzie, 2009). Because of the sensitive nature and potential legal implications of child abuse allegations, both clinicians and coders may be more reluctant to assign a definite “diagnosis” of child abuse. There also may be unique challenges in interpretation of medical records notation because of varied use of terminology; some of the synonyms for child abuse used in medical practice include “non-accidental trauma,” “inflicted injury,” and “intentional injury” (Hooft et al., 2015; Scott et al., 2009). Finally, timing may be a significant concern when using the findings of a MCPT as the gold standard, as ICD coding usually occurs soon after hospital discharge, but cases may be followed by MCPTs for variable lengths of time after hospital discharge (Scott et al., 2009).

Use of ICD-coded data in child abuse research

Health researchers must be aware of the intricacies and pitfalls of ICD coding because hospital discharge datasets (HDD) based on this coding are commonly used as data sources in epidemiologic studies (Andrews, 2015; O'Malley et al., 2005). A systematic review by Scott and colleagues in 2009 found 50 published papers that utilized ICD-coded data to examine child maltreatment; the most common use of this data was for evaluation of patterns and characteristics of injury, followed by estimation of community incidence of

abuse (Scott et al., 2009). The Kids' Inpatient Database (KID), the Nationwide Inpatient Sample and the Pediatric Hospital Information System (PHIS) are additional datasets used in publications since 2010 which have used hospital-discharge data to evaluate incidence and characteristics of physical abuse (Hooft et al., 2015). A study published in 2017 used ICD-9-coded data to obtain a national estimate of child maltreatment seen in Emergency Departments in the US; in this study an estimated 14,457 (95% CI 11,987-16,928) children under 10 years of age experienced definitive maltreatment and another 103,392 (95% CI 90,803-115,981) had findings suggestive of maltreatment (Wheeler, Shi, Xiang, Haley, & Groner, 2017).

A notable change in hospital discharge data occurred in 2015 in the United States with the transition from ICD-9 to ICD-10 coding. In terms of coding for child abuse, ICD-10 brought about expansion of available codes to include both confirmed and suspected abuse; in the case of child physical abuse what had been one diagnosis code under ICD-9 (995.54 Child Physical Abuse) became two codes under ICD-10 (T74.12 Child physical abuse, confirmed and T76.12 Child physical abuse, suspected) (Feng, Chiang & Lu, 2011). Both ICD-9 and ICD-10 include supplementary codes to indicate that an evaluation or examination for possible child abuse occurred. The primary diagnosis codes used to indicate physical child abuse, as well as external cause of injury and supplementary codes that may be indicative of physical child abuse, are detailed in Appendix B. It should be noted that for research purposes, not all investigators have used the same list of ICD codes to indicate child abuse.

Documenting the validity of ICD coding is important as ICD coding systems continue to evolve, and it may be particularly vital for child abuse research. Evidence emerged in the early 1990's that abusive injury was more prone to miscoding than accidental injury (Hooft et al., 2015). Despite the frequent usage of hospital discharge datasets in health research there are few published studies comparing ICD coding for child abuse with any other gold standard such as a hospital child abuse registry (Scott et al., 2009; Hooft et al., 2015). Most of these studies have found that ICD coding underrepresents the number of cases of abuse documented by hospital clinicians or teams (Hooft et al., 2015; Hooft, Ronda, Schaeffer, Asnes, & Leventhal, 2013; Berger et al., 2013; Somji, Plint, McGahern, Al-Saleh, & Boutis, 2011).

Comparing ICD coding to various gold standards for physical child abuse

A study in one hospital in Connecticut examined ICD-9 coding for 133 pediatric inpatients who had a determination about physical abuse recorded in a hospital registry (Hooft et al., 2013). Use of any ICD-9 code indicative of physical child abuse, from the list described in Appendix C, was compared against the gold standard of an abuse determination by a single child abuse pediatrician (CAP). ICD-9-coded data was 76.7% sensitive in detecting physical abuse (95% CI: 61.4-88.2%) and 100% specific (95% CI: 96.0-100%), using a registry of determinations made by the CAP as the gold standard (Hooft et al., 2013).

A larger study by the same primary investigator (Hooft) of 936 children from four hospitals (the same Connecticut hospital from the 2013 study plus three others in the Northeastern United States) between 2007 and 2010 found sensitivity and specificity of ICD-9 coding for physical child abuse of 73.5% (95% CI: 68.2-78.4%), and 92.4% (95% CI: 90.0-

94.0), respectively (Hooft et al., 2015). In all four hospitals, the gold standard registry determinations were again made by a child abuse pediatrician – three hospitals used determinations made at the time of patient discharge and one hospital used retrospective case review by a single CAP. Both studies included children of all ages and both considered cases in which a confirmed or strongly suspected determination of abuse was documented in the registry as positive for child abuse. All children included in this study were inpatients.

Using a similar study design, Berger and colleagues (2013) focused on abusive head trauma (AHT) in 240 children less than 5 years of age and compared ICD-9 coding with the gold standard determinations of a child protection team (CPT) in a Pittsburg, PA children’s hospital. The exact composition of this CPT is not described, but there is mention of a CPT physician, as well as communication with Child Protective Services and police for case follow-up. ICD coding sensitivity for AHT was 91.5% (95% CI: 85.8-96.2%) and specificity was 96.2% (95% CI: 92.3 to 99.7%) (Berger et al., 2013). The high sensitivity seen in this study (92%) may have been related to hospital-specific protocols and/or the more restricted age range and case definition utilized. As shown in Appendix C this study also used a longer list of ICD codes as indicative of abuse (Berger et al., 2013), which likely also contributed to the high sensitivity of coding in this study.

All three of these studies evaluated sensitivity and specificity using dichotomized categories for physical abuse, but with some variations in methodology. Each hospital used slightly different terminology for their gold standard abuse determinations. In each study, one category (Abuse) contained only those patients for which abuse was “definitive, highly suspicious, or probably,” while the other category (Not abuse) included those where abuse

was ruled out, or where the team was unsure or unable to determine whether abuse occurred. Thus, it is possible that an unknown number of cases were misclassified using the gold standard. Importantly, these three studies only included patients who had been admitted to the hospital.

A study conducted in Canada further supported the claim that ICD-coded data underestimates the number of child abuse diagnoses in hospitals (Somji et al., 2011). Again, this study used a CPT as the gold standard for determination of child abuse; the team is described as “multidisciplinary” and “hospital-based” but the exact composition is not noted. Children under 3 years of age presenting to the Emergency Department with a fracture who were evaluated for suspicion of abuse were examined retrospectively to determine the proportion that received an ICD code indicative of abuse. Caution is warranted in overinterpreting such data due to significant differences in ICD coding systems between countries and differences in study methodology, such as which ICD codes were included as indicative of abuse. However, the findings of this study were similar to those of the previously discussed publications. Among 55 children with abuse confirmed by Child Protective Services, 34 (61.8%) received an ICD code for child abuse. This proportion corresponds with the value reported in the other three studies as “sensitivity.” The authors state that they calculated a 95% confidence interval for this proportion, but the 95% CI is not reported. A mix of inpatient and outpatient evaluations were included in the study. While the authors state that inpatient coding sensitivity was higher than that of outpatients, they do not stratify their results by admission status. This study also examined several possible covariates. The researchers found that among cases evaluated for possible abuse, female

patients were 2.5 times more likely to receive an ICD code indicative of possible child abuse than were male patients (OR 2.58; 95% CI 1.02-6.50). Other covariates including age, fracture location, and presence of multiple injuries were not found to significantly affect the relationship between abuse suspicion and ICD coding for abuse. Race was not examined as a covariate in this study (Somji et al., 2011).

No published studies were identified that compared ICD-10 diagnostic codes with a child abuse registry in the US; all publications used data from prior to 2015 when ICD-9 was the national standard. However, the study discussed above from Canada (Somji et al., 2011) included 5 years of data collected after their transition to the Canadian standards for ICD-10 clinical coding (International Classification of Diseases, Tenth Revision, Canada). The authors did not stratify their findings by ICD coding system used (ICD-9 vs ICD-10), so no inferences can be made from this study regarding changes in ICD coding for abuse over time, nor the accuracy of ICD-10 coding specifically (Somji et al., 2011). ICD-10 provides more detailed coding options than ICD-9 for both confirmed and suspected abuse or neglect, along with codes for the type of abuse and information about the perpetrator (if known) in cases of confirmed abuse (Feng, Chiang & Lu, 2011; Centers for Medicare and Medicaid Services, 2018). This provides additional reason to re-examine the validity of child abuse coding since the change to ICD-10.

Public Health Significance

Child maltreatment is a significant public health problem that affected an estimated 676,000 children in the United States in 2016 (DHHS, 2018). Abuse and neglect resulted in a national fatality rate of 2.36 children per 100,000, with most deaths being children less than 3

years of age (DHHS, 2018). However, mortalities as well as case counts using all current methods of surveillance for child abuse are generally considered “the tip of the iceberg” when compared to the true incidence of abuse and neglect. The Behavioral Risk Factor Surveillance System (BRFSS) in 2010 showed that 15.9% of adults had experienced physical abuse as a child, and 10.9% experienced sexual abuse (Centers for Disease Control & Prevention, Adverse Childhood Experiences [CDC ACEs], 2015). Such abuse experiences during childhood, along with other adverse childhood experiences (ACEs) are associated with significantly higher risk for a multitude of health problems throughout adulthood, including depression, substance abuse, and chronic diseases (CDC ACEs, 2015). This has significant ramifications regarding the lifetime burden caused by child abuse for those affected and for the healthcare systems of the United States.

Several surveillance systems exist to quantify physical abuse of children in the United States, including the United States National Child Abuse and Neglect Data System (NCANDS) and the United States National Incidence Study of Child Abuse and Neglect (NIS). However, each has limitations, and none provide the same level of detail for cases seen in a hospital setting as either a registry or hospital discharge data (Fallon et al., 2010). This research project expanded the current understanding of ICD coding for child physical abuse by comparing it with a child abuse registry. Such a comparison had not previously been made in the published literature since the transition to ICD-10, nor against a registry that included the determinations of a Multidisciplinary Child Protection Team as broad in composition as this one.

Research Question and Specific Aims

This study evaluated the accuracy of ICD coding for physical child abuse, using the final abuse determinations made by the MCPT as the gold standard, at a Pediatric Level I Trauma Center in Austin, Texas during 2012-2013 and 2016-2017. Further, the study estimated the overall agreement of the ICD coding and the abuse determinations of the MCPT.

Specific aims of this study were:

1. To provide summary statistics on the age, sex, race/ethnicity, insurance type, admission status and abuse-related ICD coding related to physical child abuse, during each study period (2012-2013 and 2016-2017).
2. To estimate the sensitivity, specificity, PPV, NPV of ICD-9 and ICD-10 coding for physical child abuse, overall and by age and admission status, using the abuse determination of the MCPT as the gold standard during each study period.
3. To assess the agreement between ICD-coded hospital discharge data and the abuse determinations of the MCPT, among children evaluated for possible physical child abuse at this hospital in each of the two study periods.

METHODS

Study Setting

The study was conducted at Dell Children's Medical Center (DCMC), a Pediatric Level I Trauma Center in Austin, Texas. DCMC is the only dedicated stand-alone pediatric hospital in the region and serves a 46-county area in Central Texas (Dell Children's Medical

Center [DCMC], 2018). The hospital utilizes a Multidisciplinary Child Protection Team (MCPT) to evaluate all cases where there is a concern for abuse. The MCPT is composed of a hospital-based Child Abuse Resource and Education (CARE) Team of child abuse pediatricians, nurse practitioners, and hospital social workers, as well as local Child Protection Center staff, Child Protective Services and Childcare Licensing (CPS) case workers, Law Enforcement (LE) representatives, and the local District Attorney's (DA) offices. The CARE team provides initial in-hospital consultation and collects clinical and social information needed to assess the likelihood of abuse. All participants in the MCPT then collaborate to decide whether injuries were likely the result of child abuse. This final MCPT determination was considered the gold standard for this study and was obtained from an administrative hospital child abuse registry. An overview of the process of hospital record-keeping related to these child abuse evaluations is detailed in Appendix D.

Study Subjects

The unit of analysis was the individual patient. The study sampling frame was the hospital registry of all child abuse evaluations for children <18 years of age with hospital arrival dates during 2012-2013 and 2016-2017. Child abuse determinations from 2014 and the first half of 2015 had not been entered into the electronic child abuse registry database, and the process and platform used for this registry as well as the ICD coding system changed in 2015. Therefore, data from 2014 and 2015 could not be included in this study. Patients evaluated for solely medical abuse, sexual abuse, nutritional neglect or general neglect only (no physical abuse concern) were also excluded, as were cases missing a physical abuse

determination from the MCPT (the outcome/gold standard). Table 1 summarizes the study eligibility criteria.

Sample Size

Full census of all eligible patient records with arrival dates in 2012-2013 or 2016-2017 and otherwise meeting study criteria were included in the study. Therefore, population size was dictated by the number of records that met eligibility criteria.

Human Subjects

This retrospective study was approved by the Institutional Review Boards of University of Texas Health Science Center at Houston (UTHealth #HSC-SPH-18-0857) and the University of Texas at Austin (UT Austin #2018-07-0117). The study involved no more than minimal risk, with the main risk being breach of confidentiality. All institutional procedures were followed to ensure that patient privacy and confidentiality of medical records data were protected throughout the study. Patients or families were not contacted during the duration of this study, and individual patient information will not be shared or disclosed. All data were analyzed in a de-identified format.

Variables

Variables examined included age, sex, race/ethnicity, insurance type, admission status (inpatient vs. outpatient), MCPT physical abuse determinations (the outcome gold standard), and ICD codes for each patient. Due to clinically relevant differences in abuse patterns by age, as well as the skewed distribution of age, patients were categorized into four age groups (< 1 year old, 1 to < 4 years old, 4 to < 7 years old and \geq 7 years old). To evaluate for possible differences in ICD coding accuracy for infants compared with older children, age

was further collapsed to two similarly-sized categories for the stratified analysis: < 1 year old and \geq 1 year old. Because there were many possible combinations of race and ethnicity variables, a merged race/ethnicity variable was created. Hispanic patients of any race were categorized as Hispanic, with remaining patients categorized as non-Hispanic White or non-Hispanic Black. Non-Hispanic patients of other race or multiple races were categorized as Other race or ethnicity. These categories were chosen based on review of previous literature related to potential biases in hospital child abuse evaluations (Wood et al., 2010). Insurance type was collapsed into three categories: Privately Insured (including any private health plan or Tricare/Champus), Government Subsidized (including Medicaid and Medicaid Managed Care), and Self-Pay (including uninsured). These categories were chosen with the goal of using insurance to approximate socioeconomic status (SES), with patients on private insurance plans often considered to be of higher SES. This approach has limitations, but it has demonstrated utility when SES information is not available such as in data derived from medical records (Casey et al., 2018).

The abuse determinations of the MCPT were used to create several categorical variables to serve as the gold standard for this study. The 2012-2013 dataset included three variables for abuse determination assigned at various times in the case trajectory: (i) the initial finding from the CARE staff consultation, (ii) the determination from case discussion during a meeting of the full MCPT, and (iii) a final abuse determination. This final determination reflected the previous determinations plus any follow-up obtained after the case discussion, and this was used for study purposes unless it was missing. If the final determination was missing but there was a finding in (i) or (ii), then those were used if there

was no discrepancy between them. If the final determination was missing and there was a discrepancy between (i) and (ii), or if all determinations were missing, then the final abuse determination was considered missing and the case was excluded from the study. From 2012-2013, five options for abuse determinations were used by the MCPT: Non-Accidental Trauma (NAT), Unable to Determine/likely Non-Accidental (UTD-NAT), Unable to Determine/likely Accidental (UTD-Accidental), Accidental, and No Findings. No Findings meant that the individual was evaluated but no sign of injury was found. For this study, determinations of NAT or UTD-NAT were categorized as Abuse and all others were categorized as Not Abuse.

From 2016-2017, the MCPT used five physical abuse determination options: Abuse, Concerning for Abuse, Indeterminate, Not Abuse, and No Opinion (or insufficient information to render determination). For weighted kappa analysis, these determinations were first collapsed into three categories: Confirmed Abuse (originally Abuse), Suspected Abuse (originally Concerning for Abuse), and Not Abuse (originally Indeterminate, Not Abuse, or No Opinion). A dichotomous study variable was then created by collapsing the Confirmed Abuse and Suspected Abuse categories into a single category called Abuse; this dichotomized MCPT abuse determination (Abuse/Not Abuse) was used as the gold standard for all accuracy analysis.

The list of all ICD codes for each eligible individual was used to create a variable for whether there was any ICD code indicative of physical abuse. The ICD codes chosen for inclusion were decided *a priori* based on previous studies (Hooft et al., 2013; Hooft et al.,

2015). For the 2012-2013 study period, this included ICD-9 diagnosis codes 995.50, 995.54, 995.55, 995.59, and external cause codes E960-968.

For the 2016-2017 study period, ICD-10 codes for physical child abuse were aligned as closely as possible with the list previously used for ICD-9. Patients were categorized as having an ICD-10 code for physical abuse if they had any of the following: diagnosis code T74.12, T76.12, T74.92 or T76.92, or external cause code Y07 or Y09. In order to facilitate estimation of weighted agreement between ICD coding and MCPT determinations, a three-level ordinal variable was also created where any individual with a diagnosis code of T74.12 was categorized as Confirmed Abuse Code, T76.12 was categorized as Suspected Abuse Code, and otherwise was categorized as No Code. Appendix B contains detailed definitions of each ICD code.

Descriptive Statistics

Within each study period (2012-2013 and 2016-2017), patient demographics (age, age category, sex, race/ethnicity, admission status and insurance type) were described, and distributions compared by final MCPT determination using chi-square tests for categorical variables and the Wilcoxon rank-sum test for age as a continuous variable. Frequency tables of specific abuse-related ICD codes were also created to describe the coding patterns related to physical abuse in more detail. Frequencies of each ICD code included in the main analysis, as well as several supplementary codes related to the reason for examination were summarized. A supplementary ICD-9 code for “observation and evaluation of suspected abuse/neglect” (V71.81) was included for 2012-2013. All patients in the study population would be expected to receive this V-code by nature of the study inclusion criteria. Similarly,

frequency of use of a supplementary ICD-10 code (Z04.72) for examination for possible abuse was evaluated for the 2016-2017 study period.

Data Analysis

Contingency (2x2) tables were generated for each of the two periods (2012-2013 and 2016-2017) to tabulate ICD coding for physical child abuse by MCPT abuse determination category. Point estimates and 95% confidence intervals for the overall sensitivity, specificity, PPV and NPV were calculated using the Clopper-Pearson exact method for estimation of binomial proportions (Rosner, 2016, pp.187-193). Receiver Operating Characteristic (ROC) curves were constructed for each study period using the overall sensitivity and specificity. The area-under-the-curve (AUC) for the ROC was used to estimate the probability that ICD coding correctly differentiated between abused and not abused patients in this population, using the MCPT determinations as the gold standard (Watson & Petrie, 2010; Rosner, 2016, p. 63). Cohen's kappa and its 95% confidence interval were calculated to assess overall agreement between the dichotomized ICD coding and registry determinations for each study period, 2012-2013 and 2016-2017. This statistic corrects for agreement due to chance alone (Cohen, 1960; Warrens, 2013). Sensitivity and specificity were also estimated after stratifying on age category (< 1 year of age, \geq 1 year of age) and admission status (inpatient, outpatient).

A 3x3 contingency table was generated for the 2016-2017 period to compare the ICD-10 diagnosis code with the abuse determinations when both were categorized as Confirmed Abuse, Suspected Abuse, or Not abuse. Suspected abuse codes were newly introduced with the adoption of ICD-10. The purpose of this 3x3 categorization was to

perform a weighted kappa statistical analysis to assess the agreement among these categories. Small sample size and low overall observed sensitivity of ICD-10 coding resulted in some cells having zero observations. Therefore, the weighted kappa analysis was not reported. Instead, a supplementary analysis was conducted for the 2016-2017 study period to evaluate how choosing a different list of ICD codes to define coding for physical abuse would have affected the results of the main analysis. For this analysis, the ICD coding sensitivity and specificity estimates were repeated with the inclusion of (i) diagnosis codes only (more restrictive than the original analysis) and (ii) any physical abuse-related code including supplementary (V) codes (less restrictive than the original analysis).

All statistical analysis was performed using STATA software, version 12 (StataCorp, 2011). A p-value of 0.05 or less was considered significant for all statistical tests.

RESULTS

Results from 2012-2013 with ICD-9 Coding

During 2012-2013, a total of 396 patients were evaluated by the MCPT due to concerns for physical child abuse. Of those, 371 (93.7%) had a final MCPT abuse determination documented. Of those missing the final MCPT determination, 20 were assigned an abuse determination for study purposes using the CARE consultation or case discussion determinations. Five remaining patients were still missing a final abuse determination and were excluded from the study, leaving 391 for analysis. Of these 391 patients, 36.6% were categorized as abused and 63.4% were categorized as not abused. More than half (56.0%) of patients were less than 1 year of age, while only 6.1% were 7 years of

age or older. There were approximately equal proportions of Hispanic and non-Hispanic White patients, and 69.6% of patients had government-subsidized health insurance such as Medicaid. The proportion admitted to the hospital as inpatients was significantly higher among those determined to have physical abuse; 53.9% of those deemed abused by the MCPT were inpatients, compared to 25.8% of those deemed not physically abused ($p < 0.001$). No statistically significant differences in sex, age group, race/ethnicity or insurance type were found between the abuse group and those determined by the MCPT to be not abused in 2012-2013 (Table 2).

All 391 patients had ICD code data available, and 9.0% of those had at least one ICD code indicative of physical child abuse. The most commonly used physical abuse-related diagnosis code was 995.54 (Physical child abuse; $n=20$). A total of 76 patients (19.4% of the study population) received the expected supplementary code (V71.81) indicating an evaluation for abuse had occurred (Table 3).

Among the 35 patients receiving any of the ICD-9 codes of interest for physical abuse, 31 had been categorized as physical abuse based on MCPT determination (true positives), and 4 had not (false positives) (Table 4). Overall sensitivity of ICD-9 coding compared with the MCPT determination gold standard during this study period was 21.7% (95% CI 15.2-29.3%), and specificity was 98.4% (95% CI 95.9-99.6%) (Table 5). The area under the ROC curve (ROC-AUC) was 0.60 (95% CI 0.57-0.64) (Figure 1), and Cohen's kappa was 0.24 (95% CI 0.17-0.31) (Table 5). After repeating the analysis by age category and admission status, sensitivity of ICD coding was 18.4% (95% CI 10.5-29.0%) for those <1 year of age and 25.4% (95% CI 15.5-37.5%) for those 1 year of age or older. ICD-9

coding sensitivity for inpatients was 31.2% (95% CI 21.1-42.7%), and sensitivity for outpatients was 10.6% (95% CI 4.4-20.6%).

Results from 2016-2017 with ICD-10 Coding

During 2016-2017, a total of 312 patients were evaluated for possible physical child abuse. Nine patients were excluded because they lacked a final abuse determination, leaving 303 for analysis. Of those 303, 60.1% were categorized as abused, while 39.9% were categorized as not abused based on the gold standard MCPT determination. Children under 1 year of age made up 42.2% of this study population, while 18.5% were 7 years of age or older. There was a statistically significant difference in abuse categorization by age group, with patients 4 years of age or older more likely to be categorized as abused after MCPT evaluation and those less than 1 year of age more likely to be categorized as not abused ($p=0.005$). No statistically significant difference in abuse classification was noted based on sex, race/ethnicity, or admission status. A statistically significant difference in abuse classification was noted by insurance type, with privately insured patients more likely to be categorized as not abused and those with all other insurance types more likely to be categorized as abused ($p=0.004$) (Table 6).

All 303 patients had ICD coding data available, and 24.8% of those had at least one of the ICD-10 codes of interest for child abuse. The most frequently used ICD-10 code related to physical child abuse among the study population was T76.12 (Child physical abuse, suspected, $n=55$). Of the entire 2016-2017 study sample, only 4.3% received the expected supplementary ICD-10 code to show they had been evaluated for possible abuse or neglect (Z04.72). Further scrutiny of the data revealed that an additional 18.5% received a

code Z02.9 (Administrative examination, unspecified), which had not been included in the original list of codes of interest for physical abuse (Table 7).

Of patients that received at least one of the ICD-10 codes for physical abuse, 57 had been categorized as abused by the MCPT (true positives), while 18 had not (false positives) (Table 8). The overall sensitivity of ICD-10 coding for physical abuse was 31.3% (95% CI 24.7-38.6%), and specificity was 85.1% (95% CI 77.5-90.9%) (Table 8). The area under the ROC curve (ROC-AUC) was 0.58 (95% CI 0.54-0.63) (Figure 2), and Cohen's kappa was 0.14 (95% CI 0.06-0.23) (Table 9). When stratified by age group, sensitivity of ICD-10 coding was 31.3% (95% CI 20.6-43.8%) for those under 1 year of age and 31.3% (95% CI 23.0-40.6%) for those 1 year of age or older. Sensitivity of coding for inpatients was 52.9% (95% CI 38.5-67.1%), and for outpatients was 22.9% (95% CI 16.0-31.1%).

As a supplementary analysis, the estimations of sensitivity and specificity were repeated using different "cut-offs" to decide which ICD-10 codes to include in the analysis. Including only the most specific diagnosis codes for physical child abuse (T74.12 and T76.12) resulted in sensitivity of 27.5% (95% CI 21.1-34.6%) and specificity of 87.6% (95% CI 80.4-92.9). When all diagnosis and external cause codes from the original analysis plus the supplementary codes Z04.72 and Z62 were included, sensitivity was 35.7% (95% CI 28.8-43.1%) and specificity was 79.3% (95% CI 71.0-86.2%) (Table 10).

DISCUSSION

Validity of both ICD-9 and ICD-10 coding for physical child abuse overall was very poor in this population. Overall sensitivity of 22-31% was seen in this study, though subjectively higher sensitivity was seen among inpatients. The sensitivity of 52.9% for ICD-

10 coding found among inpatients in the 2016-2017 study period most closely approached the 60-90% sensitivity found in other publications (Hooft et al., 2013; Hooft et al., 2015; Berger et al., 2013; Somji et al., 2011). This was not surprising given that most of the other studies included only inpatients. For both study periods, agreement between ICD coding and MCPT determinations based on Cohen's kappa was only marginally better than that expected by chance alone (McHugh, 2012). The probability of ICD coding correctly differentiating between abused and not abused patients based on the ROC-AUC was only modestly better than 50%.

The accuracy of ICD-coding depends on many factors, including the training and experience level of coders, and the clarity of findings documented in the medical record. This study did not attempt to ascertain the factors involved in incorrect coding. Lower accuracy in this study compared with prior studies could be related to an overall lower accuracy in all ICD coding throughout the hospital, as well as possible accuracy problems specific to child abuse. All ICD coding accuracy depends on adequate training, experience and guidelines provided to professional coders as well as on a shared language among clinicians that is understood by coders. This study did not compare ICD coding for physical child abuse with ICD coding for other conditions in the same hospital. However, previous studies suggest ICD coding for child abuse may be more inaccurate than for other conditions. This may be due to reluctance on the part of both clinicians and coders to document a diagnosis of abuse, or to the wide variety of terminology used to characterize child abuse findings (Scott et al., 2009; Hooft et al., 2013). Timing may also have been a key factor, as evidenced by the higher sensitivity of coding in both time periods for inpatients as compared to outpatients. The

process of making determinations about physical abuse may take time, and ICD coding particularly for outpatients may be performed before the MCPT has made their final determination. This study also only looked at abuse-related ICD coding for the specific visit when the abuse evaluation took place, not subsequent visits.

Description of the patient demographics by physical abuse category was undertaken for three purposes. The first was to provide detailed information on the population to which these results might be generalized. The second purpose was to document how the study populations may have differed during the two study periods, aside from the use of ICD-9 vs ICD-10. The final purpose of the descriptive statistics was to look for any evidence of bias in the MCPT determinations of abuse. From 2012-2013, 37% of patients evaluated were categorized as abused, while from 2016-2017 that number was 60%. The total number of evaluations in 2016-2017 was lower by 29% compared to 2012-2013; fewer referrals for abuse evaluation were made, but of the patients evaluated more were determined to be abused. This appeared to coincide with a shift in the age distribution of children evaluated, with a higher proportion of older children, and lower proportion of infants in the later study period. These changes in abuse evaluations over time are likely related to increased knowledge of providers regarding which patients should be evaluated by the MCPT as well as to a variety of changes in hospital protocols. Thus, it was appropriate to analyze the two study periods separately because they involved quite distinct study populations. Except for insurance status in the 2016-2017 study period, there were not significant differences in demographics by abuse classifications based on the MCPT determinations. This provides

evidence that the MCPT abuse determinations were reasonably unbiased by the factors evaluated.

All patients in this study population would be expected to receive an ICD code for evaluation or examination of possible physical child abuse because they were all evaluated due to abuse concerns. However, a surprisingly low proportion received this code in either study period. For 2016-2017, the frequency of use of the ICD-10 code for “Administrative examination, unspecified” (Z02.9) was also an unexpected finding. This general examination code (Z02.9) may have been used by the hospital coders in lieu of the more specific abuse-related examination code (Z04.72). Replication of this finding among patients evaluated for child abuse in other hospitals could be helpful, as could evaluation of how this ICD-10 code is used in various patient populations. If use of code Z02.9 in the context of hospital abuse evaluations seems consistent among patients evaluated for abuse, then researchers might want to include it when screening ICD-coded data for possible abuse cases.

In 2012-2013, two out of the four instances of false positive ICD-9 coding were included as positive in the study solely because of an external cause of injury code for assault (ICD-9 code E968). Therefore, they would not have been considered positive if a narrower list of ICD-9 codes had been chosen. The other two false positives were coded as an actual physical abuse diagnosis (ICD-9 code 995.54) even though they were classified as Not Abuse based on the MCPT determination. This could be attributable to coder error, unclear notes in the medical record, or timing of ICD coding process. Coders may have assigned a diagnosis code based on initial evaluation or notes in the medical record at the time of hospital discharge, but the MCPT may have later gathered additional information that helped inform

their final determination that the patient was not actually abused. Misclassification may also have occurred within the study design, because for example the cases that were listed as UTD-Accidental were classified in the study as Not Abuse.

In 2016-2017, there was one out of the 18 false positives that was classified as positive because of an external cause of injury code (Y07). This code was related to a non-physical type of child abuse or neglect in this patient. The other 17 of the 18 false positives (94.4%) were considered positive based on presence of the codes for Suspected Physical Abuse (ICD-10 code T76.xx). The addition of suspected abuse categories in ICD-10 was likely intended to provide more granularity to abuse diagnosis. However, these new codes were utilized inconsistently in this population, as were the codes for evaluation following possible physical abuse. This makes it difficult to differentiate, based on ICD coding alone, between patients who were simply evaluated for possible abuse and patients for which abuse was reasonably suspected after that evaluation. Sample size in this study was insufficient to evaluate weighted agreement between ICD-10 coding and MCPT determination using the categories of Confirmed Abuse, Suspected Abuse and Not Abuse. However, the false positives associated with use of suspected abuse diagnosis codes suggests that clarification on when coders should use these codes would be helpful.

It has been somewhat difficult to compare findings from previous studies on this subject because of the varying list of codes that have been chosen by different authors and the different study populations. As shown in the 2016-2017 study period, choice of which ICD-10 codes to include as positive for physical abuse resulted in only a modest change in

results. Sensitivity of ICD coding was remarkably low regardless of the list of ICD codes chosen.

CONCLUSION

The goal of this study was to evaluate accuracy of ICD-coding for physical child abuse, to better inform the use of such data for research and public health surveillance. The study population included patients seen in only one hospital and only those evaluated for possible abuse. Both restrictions limit generalizability of findings from this study.

Misclassification bias could have occurred in both the ICD-coding and MCPT determinations. An advantage of the MCPT classification system used at this hospital from 2012-2013 was the lack of an indeterminate category; patients for the whom the MCPT were unable to make a definitive determination were categorized as Likely Non-Accidental Trauma or Likely Accidental. This was another way in which this study data differed from that used in previous studies. The choice of how to dichotomize the MCPT determination into Abuse or Not Abuse for 2016-2017 was done conservatively, categorizing a small number of indeterminate cases as Not Abuse. As a result, some truly abused patients may have been incorrectly classified. Medical records review of indeterminate cases as well as those missing a final determination might have helped reduce misclassification.

Another study limitation was possible bias in the MCPT evaluation process that was used as the gold standard. However, the large size, broadly inclusive composition, and high level of training of the team members should have helped minimize the effect of any individual biases. The sensitivity, or ability of ICD-coding to correctly identify patients who have experienced physical child abuse, is of primary interest to those wishing to use ICD-

coded data for abuse surveillance purposes. The results of this study should prompt extreme caution before using ICD-coded data alone to estimate incidence or prevalence of physical child abuse. Authors should specify which ICD codes are included in any analysis, as well as how MCPT abuse determinations were classified, as these factors may affect the results. The findings of this study, along with previous studies of ICD-coding accuracy may help justify the maintenance of hospital registries containing detailed information on physical abuse cases. Such registries require commitment of resources to maintain, but this appears to be worth the improvement in quality of data. High-quality data is critically important to guide child abuse prevention programs (both within the hospital and the community) to where they are needed most. The results of this study also highlight the importance of ongoing quality improvement efforts to maximize the accuracy of ICD coding at hospitals.

TABLES

Table 1: Study eligibility criteria

Child Abuse Registry Inclusion Criteria:

All children < 18 years old evaluated at Dell Children's Medical Center (DCMC) for child abuse or neglect, as evidenced by CARE team (Inpatient or Outpatient CARE clinic) involvement, with arrival dates during 2012-2013 or 2016-2017. May have included any of the following:

- Inpatient CARE consult
- Referral to outpatient CARE Clinic (by Emergency Department (ED), Primary Care Provider, CPS, law enforcement, outside Hospital or another source)
- Forensic Assessment Center Network referral (w/direct contact by CARE team) – communication platform for CPS workers and providers
- Involvement in CARE case review meeting
- Procedure ordered by CARE team (i.e. sibling evaluation – including sibling skeletal survey, whether CARE consulted or not)
- Suspicious ED death
- Abuse suspected in other hospital department as evidenced by CPS or law enforcement involvement by DCMC for this visit and/or concern charted

Exclusion Criteria:

- Cases evaluated for solely medical abuse, sexual abuse, nutritional neglect or general neglect only (no physical abuse concern)
 - Cases missing a final physical abuse determination
-

Table 2: Descriptive statistics of patients evaluated by the MCPT for possible physical abuse during 2012-2013 (n=391)^a

| | Physical Abuse (MCPT determination) n=143 (36.6%) | Not physical abuse (MCPT determination) n=248 (63.4%) | p-value |
|-----------------------|---|---|---------|
| Sex | n (%) | n (%) | |
| Male | 75 (52.5%) | 146 (58.9%) | 0.217 |
| Female | 68 (47.6%) | 102 (41.1%) | |
| Missing | 0 | 0 | |
| Age in months | median (IQR) ^b 11 (27 months) | median (IQR) ^b 9 (18 months) | 0.461 |
| Age group | n (%) | n (%) | |
| < 1 year | 76 (53.2%) | 143 (58.1%) | 0.081 |
| 1 - < 4 years | 47 (32.9%) | 78 (31.7%) | |
| 4 - < 7 years | 13 (9.1%) | 8 (3.3%) | |
| ≥ 7 years | 7 (4.9%) | 17 (6.9%) | |
| Missing | 2 | 0 | |
| Race/ethnicity | n (%) | n (%) | |
| non-Hispanic White | 54 (38.0%) | 80 (32.7%) | 0.187 |
| non-Hispanic Black | 21 (14.8%) | 25 (10.2%) | |
| Hispanic | 53 (37.3%) | 118 (48.2%) | |
| Other | 14 (9.9%) | 22 (9.0%) | |
| Missing | 1 | 3 | |
| Insurance Type | n (%) | n (%) | |
| Private Insurance | 22 (15.6%) | 46 (19.0%) | 0.642 |
| Government Subsidized | 104 (73.8%) | 168 (69.4%) | |
| Self-Pay/Other | 15 (10.6%) | 28 (11.6%) | |
| Missing | 6 | 2 | |
| Admission status | n (%) | n (%) | |
| Outpatient | 66 (46.1%) | 184 (74.2%) | <0.001 |
| Inpatient | 77 (53.9%) | 64 (25.8%) | |
| Missing | 0 | 0 | |

^aFive observations excluded due to missing MCPT determination, ^bIQR = Interquartile range

Table 3: Frequency of use of ICD-9 codes related to physical child abuse in 2012-2013

| ICD-9 code used | Physical abuse (MCPT) n=143 | Not physical abuse (MCPT) n=248 |
|---|-----------------------------|---------------------------------|
| Included in final analysis: | | |
| 995.50 Child abuse, unspecified | 1 | 0 |
| 995.54 Child physical abuse | 18 | 2 |
| 995.55 Shaken baby syndrome | 3 | 0 |
| 995.59 Other child abuse & neglect | 1 | 0 |
| E967 Perpetrator of child abuse | 19 | 0 |
| E960-966, 968-969 Assault | 8 | 2 |
| Not included in analysis: | | |
| V71.81 Observation and evaluation for suspected abuse/neglect | 20 | 56 |

A single patient may have more than one abuse-related ICD code so may be represented more than once in this table

Table 4: Contingency (2x2) table of MCPT determinations and physical abuse related ICD-9 coding in 2012-2013

| | MCPT Abuse (+) | MCPT Not abuse (-) | Total |
|-------------------------------|----------------|--------------------|-------|
| ICD-9 physical abuse code (+) | 31 | 4 | 35 |
| ICD-9 physical abuse code (-) | 112 | 244 | 356 |
| Total | 143 | 248 | 391 |

Dichotomized MCPT abuse determinations (gold standard) vs. whether patient received at least one of included ICD-9 codes (995.50, 995.54, 995.55, 995.59, or E960-E968)

Table 5: Analysis of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV), Area-under-the-ROC-curve (ROC-AUC) and Cohen's Kappa statistic for ICD-9 coding of physical child abuse in 2012-2013

| | |
|--|-------------------|
| Sensitivity % (95% CI) | 21.7% (15.2-29.3) |
| Specificity % (95% CI) | 98.4% (95.9-99.6) |
| Positive predictive value (PPV) % (95% CI) | 88.6% (73.3-96.8) |
| Negative predictive value (NPV) % (95% CI) | 68.5% (63.4-73.3) |
| ROC-AUC (95% CI) | 0.60 (0.57-0.64) |
| Cohen's kappa (95% CI) | 0.23 (0.17-0.31) |

Table 6: Descriptive statistics of patients evaluated by the MCPT for possible physical abuse during 2016-2017 (n=303)^a

| | Physical Abuse (MCPT determination) n=182 (60.1%) | Not physical abuse (MCPT determination) n=121 (39.9%) | p-value |
|-----------------------|---|---|---------|
| Sex | n (%) | n (%) | |
| Male | 110 (60.4%) | 67 (55.4%) | 0.381 |
| Female | 72 (39.6%) | 54 (44.6%) | |
| Missing | 0 | 0 | |
| Age in months | median (IQR) ^b 24.5 (64 months) | median (IQR) ^b 11.5 (33 months) | 0.008 |
| Age group | n (%) | n (%) | |
| < 1 year | 67 (36.8%) | 60 (50.0%) | 0.006 |
| 1 - < 4 years | 45 (24.7%) | 34 (28.3%) | |
| 4 - < 7 years | 33 (18.1%) | 7 (5.8%) | |
| ≥ 7 years | 37 (20.3%) | 19 (15.8%) | |
| Missing | 0 | 1 | |
| Race/ethnicity | n (%) | n (%) | |
| non-Hispanic White | 71 (39.0%) | 46 (38.0%) | 0.878 |
| non-Hispanic Black | 31 (17.0%) | 17 (14.1%) | |
| Hispanic | 66 (36.3%) | 48 (39.7%) | |
| Other | 14 (7.7%) | 10 (8.3%) | |
| Missing | 0 | 0 | |
| Insurance Type | n (%) | n (%) | |
| Private Insurance | 21 (11.5%) | 30 (24.8%) | 0.004 |
| Government Subsidized | 143 (78.6%) | 86 (71.1%) | |
| Self-Pay/Other | 18 (9.9%) | 5 (4.1%) | |
| Missing | 0 | 0 | |
| Admission Status | n (%) | n (%) | |
| Outpatient | 131 (72.0%) | 93 (76.9%) | 0.343 |
| Inpatient | 51 (28.0%) | 28 (23.1%) | |
| Missing | 0 | 0 | |

^aNine observations excluded due to missing MCPT determination, ^bIQR = Interquartile range

Table 7: Frequency of ICD-10 codes related to physical child abuse, 2016-2017

| ICD-10 code used | Physical abuse (MCPT) n=182 | Not physical abuse (MCPT) n=121 |
|--|--------------------------------|------------------------------------|
| Included in analysis: | | |
| T74.12 Child physical abuse, confirmed | 10 | 0 |
| T74.92 Unspecified child maltreatment, confirmed | 2 | 0 |
| T76.12 Child physical abuse, suspected | 40 | 15 |
| T76.92 Unspecified child maltreatment, suspected | 3 | 2 |
| Y07 Perpetrator of assault, maltreatment | 6 | 2 |
| Y09 Assault by unspecified means | 3 | 0 |
| Not included in analysis: | | |
| Z04.72 Examination & observation following alleged physical abuse | 7 | 6 |
| Z62 – Problems related to upbringing (such as child welfare custody, etc.) | 7 | 1 |
| Z02.9 Administrative examination, unspecified | 37 | 19 |

A single patient may have more than one abuse-related ICD code so may be represented more than once in this table

Table 8: Contingency (2x2) table of MCPT determinations and physical abuse-related ICD-10 coding in 2016-2017

| | MCPT Abuse (+) | MCPT Not abuse (-) | Total |
|--------------------------------|----------------|--------------------|-------|
| ICD-10 physical abuse code (+) | 57 | 18 | 75 |
| ICD-10 physical abuse code (-) | 125 | 103 | 228 |
| Total | 182 | 121 | 303 |

Dichotomized MCPT abuse determinations (gold standard) vs. whether patient received at least one of included ICD-10 codes (T74.12, T74.92, T76.12, T76.92, Y07 or Y09)

Table 9: Analysis of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV), Area-under-the-ROC-curve (ROC-AUC) and Cohen's Kappa statistic for ICD-10 coding of physical child abuse in 2016-2017

| | |
|--|-------------------|
| Sensitivity % (95% CI) | 31.3% (24.7-38.6) |
| Specificity % (95% CI) | 85.1% (77.5-90.9) |
| Positive predictive value (PPV) % (95% CI) | 76.0% (64.8-85.1) |
| Negative predictive value (NPV) % (95% CI) | 45.2% (38.6-51.9) |
| ROC-AUC (95% CI) | 0.58 (0.54-0.63) |
| Cohen's kappa (95% CI) | 0.14 (0.06-0.23) |

Table 10: Supplementary analysis using different lists of ICD-10 codes to define cut-off for positive for a physical abuse ICD-10 code in 2016-2017

| Diagnosis codes T74.12 or T76.12 only | | Any code (T74.12, T74.92, T76.12, T76.92, Y07, Y09, Z04.72, or Z62) | |
|--|-------------------|--|-------------------|
| Sensitivity | 27.5% (21.1-34.6) | Sensitivity | 35.7% (28.8-43.1) |
| Specificity | 87.6% (80.4-92.9) | Specificity | 79.3% (71.0-86.2) |
| PPV | 76.9% (64.8-86.5) | PPV | 61.8% (61.8-81.2) |
| NPV | 44.5% (38.1-51.1) | NPV | 45.1% (38.3-52.0) |

FIGURES

Figure 1: Receiver Operating Characteristic (ROC) curve for ICD-9 coding for physical child abuse in 2012-2013

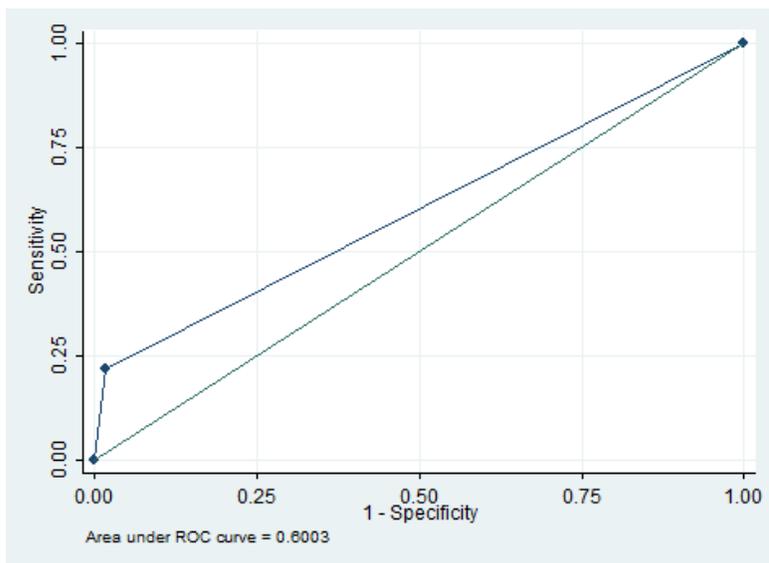
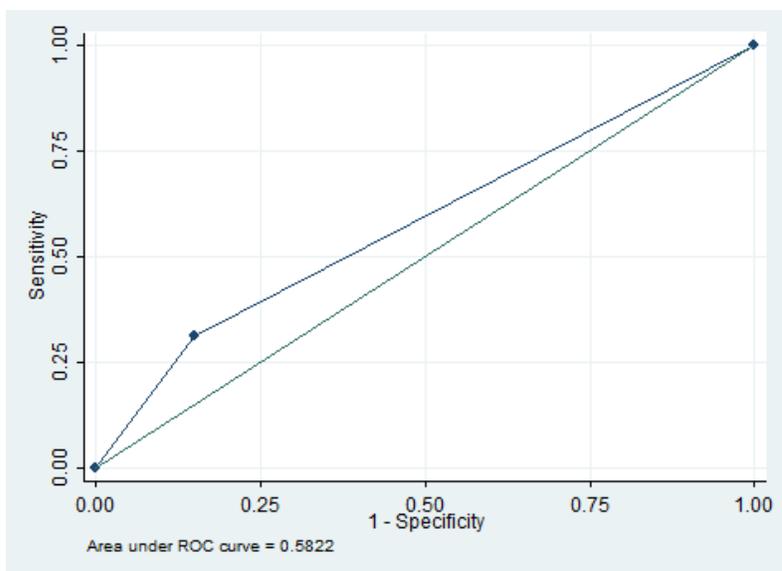


Figure 2: Receiver Operating Characteristic (ROC) curve for ICD-10 coding for physical child abuse in 2016-2017



APPENDICES

Appendix A: Examples of indicators of child abuse used in making MCPT determinations

Injury pattern or specific injury characteristics

- Metaphyseal or transverse extremity fractures
 - Rib fractures
 - Multiple fractures of different ages
 - Unusual burn or bruising patterns
 - Ear and chest bruising
-

History of injury indicators

- History of injury provided by caregiver changes over time
 - No history of trauma is provided to explain injury
 - No clear history provided, but there is speculation as to what may have happened
 - Patient disclosure that injury was inflicted
-

Mechanism of injury indicators

- Mechanism provided is inconsistent with developmental age (ex: reporting that an infant rolled off bed when they are 2 weeks old)
 - Injury is inconsistent with stated mechanism
-

Family psychosocial risk factors

- Involvement with Child Protective Services
 - Involvement with Law enforcement
 - Parental history of physical/sexual abuse
 - Substance abuse
 - Domestic violence
 - Mental illness
 - Psychosocial stressors
 - Weapons in the home
-

Additional law enforcement findings

- Results of questioning by investigators
 - Injury site investigation
 - Confession by perpetrator
-

Appendix B: ICD codes indicative of physical child abuse

ICD-9-CM

Diagnosis Codes

Codes beginning in 995, specifically:

- 995.5 Child maltreatment syndrome
 - 995.50 Child abuse, unspecified
 - 995.54 Child physical abuse
 - 995.55 Shaken baby syndrome
 - 995.59 Other child abuse and neglect

Supplementary Classification of Factors Influencing Health Status and Contact with Health Services

V71.81 Observation and evaluation for suspected abuse and neglect

External cause codes “E codes”

E967 Perpetrator of child and adult abuse
E960.0, E961-966, or E968.0-968.9 Assault

ICD-10-CM

Diagnosis Codes

Codes beginning in T74 or T76, specifically:

- T74.12 Child physical abuse, confirmed
- T76.12 Child physical abuse, suspected
- T74.92 Unspecified child maltreatment, confirmed
- T76.92 Unspecified child maltreatment, suspected

Supplementary Classification of Factors Influencing Health Status and Contact with Health Services

Z04.72 Encounter for examination and observation following alleged child physical abuse
Z62 – Problems related to upbringing (such as child welfare custody, etc.)

External cause codes “E codes”

Y07 Perpetrator of maltreatment & neglect
Y09 Assault

Appendix C: Summary of studies of ICD coding for physical child abuse in hospitals

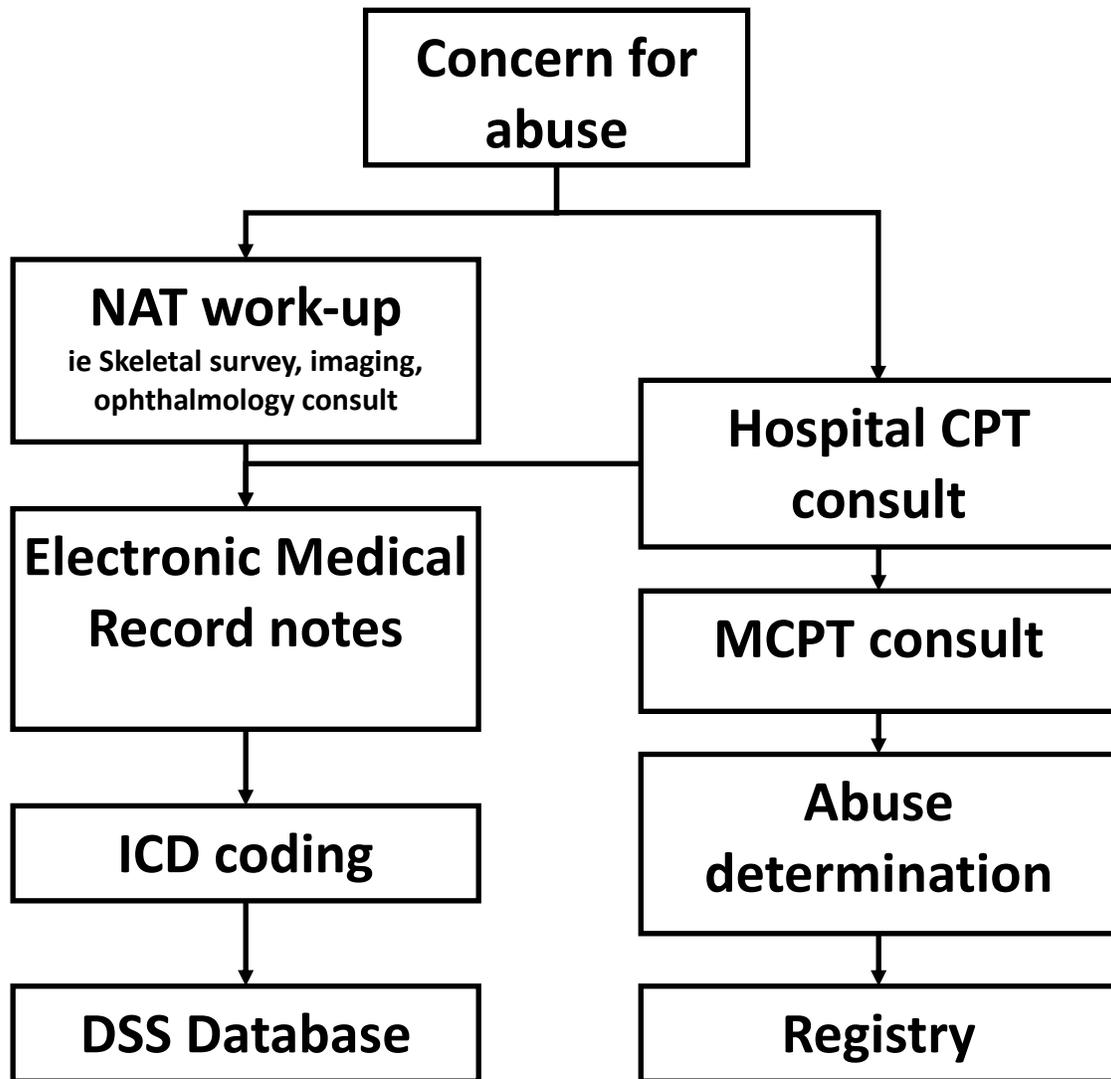
| Study | n | Study population | Gold standard determination made by | Results (“sensitivity”) of ICD coding as compared to the gold standard of each study |
|----------------------------|----------|--|--|--|
| Hoof et al., 2013 | 133 | Pediatric inpatients, (no age restriction) evaluated for possible physical abuse | Child abuse pediatrician (CAP) | 76.7% (95% CI 61.4-88.2%) of patients <i>determined to have injuries resulting from physical abuse by the CAP</i> received ICD coding indicative of abuse ^a |
| Hoof et al., 2015 | 936 | Pediatric inpatients (no age restriction) evaluated for possible physical abuse | CAP | 73.5% (95%CI 68.2-78.4%) of patients <i>determined to have injuries resulting from physical abuse by the CAP</i> received ICD coding indicative of abuse ^a |
| Berger et al., 2013 | 223 | Inpatients <5 years of age with head trauma evaluated for possible abuse | Child Protection Team (CPT) | 92.0% (95% CI 85.8-96.2%) of patients <i>determined to have abusive head trauma by CPT</i> received ICD coding indicative of child abuse ^b |
| Somji et al., 2011 | 216 | Inpatients and outpatients seen in emergency department <3 years of age with at least one fracture, evaluated for possible abuse | CPT | 61.8% (no 95% CI reported) of those <i>with confirmation of abuse by CPT</i> received ICD coding indicative of child abuse ^c |

^aICD-9-CM codes included 995.50, 995.54, 999.55, 995.59, E960.0, E961-966, E 968.0-968.9, or E967.0-967.9

^bICD-9-CM codes included 995.50, 995.54, 995.59 E960.0, E967, E968.1, E968.2, E968.8, E968.9, E987, E988.8, E988.9, 781.0–781.4, 781.8, 800, 801, 803, 804.1–804.4, 804.6-804.9, 850, 851, 852.0–852.5, 853.0, 853.1, 854.0, 854.1, 925.1, 950.0–950.3, 959.01, 995.55

^cICD-9-CM codes included 995.50, 995.54, 999.55, 995.59, E960.0-969, V15.41, V61.21, V68.2, V71.6, V71.81; and ICD-10-Canada T74.1, T74.8, T74.9, X85-Y07, Z04.51, Z04.58, Z04.8, Z61.6

Appendix D: Data sources for ICD codes and MCPT child abuse determinations from Dell Children's Medical Center



NAT = Non-accidental Trauma

ICD = International Classification of Diseases

DSS = Decision Support Services/Hospital administrative database

Hospital CPT = Hospital Child Protection Team (child abuse pediatrician, nurse practitioners, hospital social workers)

MCPT = Hospital CPT + CPS/Childcare Licensing, law enforcement, District Attorney's office

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