Standardizing Radiological Findings for Non-Accidental Trauma in the Pediatric Population

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Abstract

The objective of this project was to review skeletal survey reports and examine the differences in reporting of non-accidental trauma in patients with similar radiological findings. The overall purpose of this project is to develop a standardized reporting system for radiological findings suspicious for non-accidental trauma. Ten years' worth of skeletal survey reports were obtained on over 1,500 pediatric patients. These reports were individually reviewed and their findings were categorized in a table separating findings suspicious for non-accidental trauma. After data collection, analysis was completed to inspect the consistency of reports amongst studies with similar fractures specifying non-accidental trauma. The comparison was made between reports containing long bone fractures, metaphyseal corner fractures, rib fractures, or any combination of these. It was concluded that there are inconsistencies in reporting of non-accidental trauma in reports with similar patterns of these fractures. We propose a Skeletal Survey – Reporting and Data System (SS-RADS) score which will help radiologist standardize their reporting methods for more consistent interpretations and clinical outcomes.

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Introduction

Child abuse, also referred to *non-accidental trauma*, is a common occurrence that is often overlooked or missed by the medical community. Every year, approximately 1 million children are injured and five thousand killed due to non-accidental trauma in the United States[10]. The child's age is the single most important risk factor: it is also estimated that 25-56% of all fractures in children under one year of age are due to abuse[17]. Vulnerable and incapable providing their own history, these infants must be given extra attention in the clinical setting where non-accidental trauma is suspected.

Several factors must be taken into consideration when evaluating a child suspected for abuse. A thorough history and physical is vital in the assessment of a pediatric patient suspected of non-accidental trauma. Suspicion is warranted when there are inconsistencies between the mechanism of injury described by the parent or caregiver and the child's injuries. Additionally, unwitnessed injuries, injuries attributed to the patient's siblings, injuries inconsistent with the child's age, and injuries inconsistent with the mechanism presented should raise the question for abuse[15,16]. For example, femoral shaft fractures in children who are unable to move or walk (under the age of 1) are due to abuse 60% of the time[24].

It is important to note that no physical finding or musculoskeletal injury is pathognomonic for child abuse. The diagnosis must be determined through a complete evaluation of the child's history, physical examination, radiographs, laboratory tests, past injuries, medical problems, and immunization status. Interactions between the child and parent or caregiver may also provide information as to whether there is potential for abuse[12]. In addition, discussions with friends and family members may provide insight and aid in determining whether abuse is possible. A complete and thorough physical examination must not be overlooked; retinal hemorrhages, cutaneous bruising, and neurologic deficits often accompany non-accidental trauma victims[9,23]. It is unlikely that a primary care physician would be able to investigate all of these features in a single visit. The goal of the medical evaluation is to determine whether the level of suspicion is sufficient to warrant making a report to Child

Protective Services (CPS). Once this report is made, a complete investigation will determine whether abuse has occurred.

When physical abuse is suspected in a child with the appropriate history and physical, a skeletal survey x-ray can be ordered by the primary care physician to examine the bones of the child. This study is a small, but important part of determining whether abuse is likely. The purpose of the skeletal survey is to document the presence of findings suspicious for abuse so that the child can be removed from exposure to the abuser[10]. The standard skeletal survey includes anterior/posterior, and lateral views of the skull and chest; lateral views of the spine; anterior/posterior views of the pelvis, long bones of the extremities, and feet; and posteroanterior oblique views of the hands[3]. According to The American Academy of Pediatrics and the American College of Radiology, all children younger than two years of age in whom child abuse is suspected should have a skeletal survey to evaluate for abuse[1,2,3,4].

Although no fracture or radiograph finding is one hundred percent specific for abuse, certain findings are more suspicious and may help guide a clinician in their management of the patient's case. Posterior rib fractures that occur near the costovertebral joints are highly suggestive of abuse[10]. Lacking a history of a motor vehicle accident, violent trauma, or post surgical history, this type of fracture has a 70% probability of abuse[22]. This is thought to occur when a child or infant is squeezed by an adult around the thorax. Children's ribs are flexible and difficult to fracture such that cardiopulmonary resuscitation does not reproduce posterior rib fractures[8]. As a result, this type of fracture should raise high suspicion for non-accidental trauma, particularly in the presence of bilateral posterior rib fractures[7]. Another finding that is highly specific for abuse is the classic metaphyseal lesion, also referred to as a 'corner' or 'bucket handle' fracture[10]. This fracture extends through the primary spongiosa of the metaphysis, the weakest portion of the bone. These fractures occur when the extremity is pulled or twisted with force, or when a child a shaken[18]. In confirmed non-accidental traumas, these metaphyseal fractures accounted for 11-28% of radiographic findings[9]. When viewed tangentially on radiographs, the broken metaphyseal rim will appear as a corner fracture. When viewed at an angle, the fracture will resemble a bucket handle[10]. Long bone fractures are

another set of findings that vary in specificity for non-accidental trauma. In a study that looked at 350 fractures in children in the emergency department, over 50% of the documented abusive fractures included long bone fractures. These included humeral, femoral, tibular, and fibular fractures[15]. In other studies of fractures occurring in abused children, approximately 20% of the fractures involved the femoral long bone[19,20]. Again, age and clinical context play a major role in determining whether these fractures are likely to be intentional or accidental. In another study, it was determined that 20% of femoral fractures in children between the ages of two and three years were a result of abuse. This differs from infants under the age of one year, where 60% of femoral fractures were non-accidental[14]. Whether a child can walk is the single most important predictor of inflicted injury in isolated femur fractures[22]. Multiple bilateral long bone injuries in young children also make non-accidental trauma more likely[13].

Other radiographic findings that are suspicious for non-accidental trauma, but are less common, include fractures of the sternum, scapula, and spinous process. Skull fractures in children younger than 18 months of age also suggests non-accidental trauma. Spinal fractures comprise two to three percent of all pediatric injuries[10]. They are generally caused by direct trauma or forceful acceleration/deceleration forces, and are most common in the lower thoracic and upper lumbar spine[14]. Complex skull fractures were initially reported as being more specific for abuse, but study reports showed varying results[23]. The combination of three or more of the fractures discussed above increases the likelihood of abuse four to six fold compared to children with only one of the fractures[13, 15].

The key to successful early detection of non-accidental trauma in pediatric patients requires that all medical personnel have an understanding of the injury patterns that can occur. One method that may improve the chances of early detection of abuse is through the skeletal survey radiographic evaluation. In an early study, it was estimated that an abused child who is returned to an unsafe home environment is at 50% risk for further injury and 10% risk of death over the next 5 years[11]. The skeletal survey and its report findings may play a pivotal role in helping a clinician determine how suspicious they should be in the case of positive findings. The purpose of this project is to examine whether or not there are inconsistencies in reporting of

non-accidental trauma in skeletal surveys that are suspicious for such findings. We hypothesize that skeletal survey reports vary amongst radiologist. This can lead to uncertainty amongst primary care physicians in determining what the next best step is for the care of a patient. Ultimately, depending on the results, we would like to suggest a standardized reporting system for fractures that are suspicious for non-accidental trauma that will make interpreting these reports simpler for a primary care physician.

Materials and Methods

A list of patients that had skeletal survey reports ordered at St. Joeseph's Hospital and Medical Center in Phoenix from 03/2000 to 01/2010 was obtained from the hospital medical data base. This list contained every patient who had ever had a skeletal survey ordered for any reason over the ten year span. An F309 form determined that an IRB would not be required for the project. After the list was obtained, a Microsoft Excel Spreadsheet was created that categorized every patient's skeletal survey finding. The columns were labeled according to the fractures that the research found to be most suspicious of non-accidental trauma. These fractures were in previous studies determined to be more significant and specific for child abuse. The columns included long bone fractures, rib fractures, metaphyseal corner fractures, sternum fractures, scapular fracture, spinous process fractures, healing fractures, and skull fractures. Additional columns were added which included osteopenia, rickets, osteogenesis imperfecta, and vitamin D deficiency. Finally, a column was added titled 'SNAT noted' to determine which skeletal surveys had a specific note that stated that there was suspicion for non-accidental trauma. Patient identifiers, date, indication of study, and radiologist who read the report were also labeled into columns. The purpose of these columns was to allow clear documentation of what the skeletal surveys contained in their report.

After the Excel spreadsheet was created, each patient's skeletal survey report was opened starting from the most recent. Data was entered into the spreadsheet based on report findings. An 'x' was added under each column if that finding mentioned in the report. A sample screen shot of this spreadsheet is shown in Figure 1. This was completed until all the skeletal surveys had been reviewed and entered accordingly into the excel spreadsheet. Once the data was collected, a review of the records was completed and patients who had multiple SNAT survey's were removed. Patients whose records were unable to be retrieved were also removed. Of the 1,503 initial records, 1,490 were kept for analysis after the review process.

The 1,490 records were then separated into two categories. The first category contained the reports which specifically mentioned that the findings were *suspicious for non-accidental trauma.* The second category contained all the other skeletal survey's that did not specially

mention SNAT. Analysis was completed on these two sets of data to determine whether or not there was a difference in report methods amongst various fractures. For the purpose of this report, the data that was compared was simplified into seven categories. The seven categories of fractures were: long bone fractures (LBF) only, metaphyseal corner fractures(MCF) only, rib fractures (Rib) only, LBF+MCF-Rib, LBF+Rib-MCF, Rib+MCF-LBF, and LBF+MCF+Rib. The rational for these specific fracture combinations was that these were found to be the most specific for child abuse. These seven categories of fractures were compared between the groups of reports that specifically mentioned SNAT and the reports that did not mention SNAT at all. *The Fischer Exact Test* is a statistical method that was used to determine whether the two sets of data were significantly different. The purpose of comparison was to examine whether final radiology reports varied in their presentation of the same fractures.

Results

	Totals (n=1490)	SNAT (n=67)	SNAT %	SNAT 95% CI	Non-SNAT (n=1423)	Non-SNAT %	Non-SNAT 95% CI	P-Value
LBF-MCF-Rib	186	9	13.4	5.24%-21.6%	177	12.4	10.7%- 14.2%	0.85
MCF-LBF-Rib	21	7	10.4	3.13%-17.8%	14	0.984	0.47%-1.49%	<0.01
Rib-LBF-MCF	60	19	28.4	17.6%-39.2%	41	2.88	2.01%-3.75%	<0.01
LBF+MCF-Rib	20	10	14.9	6.4%-23.5%	10	0.702	0.27%-1.13%	<0.01
LBF+Rib-MCF	23	9	13.4	5.27%-21.6%	14	0.984	0.47%-1.49%	<0.01
MCF+Rib-LBF	7	4	5.97	0.3%-11.6%	3	0.211	-0.03%-0.45%	<0.01
LBF+MCF+Rib	7	6	8.95	2.12%-15.8%	1	0.070	-0.07% 0.21%	<0.01

Table 1: This chart compares the skeletal surveys which contained the phrase SNAT vs those which did not. Each column defines the type of fractures present. For example, (LBF-MCF-Rib) signifies that there is a Long Bone Fracture present, but no Metaphyseal Corner Fractures or Rib Fractures. The (-) denotes negative. The p-values are given using the Fischer Exact Test and shows whether there is a difference in reporting of SNAT amongst the types of fractures compared. For example, the second row compares MCF fracture, without LBF or Rib Fractures. It can be seen that there 7 reports which contained only MCF that mentioned SNAT directly in the report. It can also be seen that there were 14 same findings that did not mention SNAT in the report. Using the first row as another example, it can be seen that of the 1,490 skeletal surveys examined, 186 of them had only long bone fractures. Of the 1,490 skeletal surveys, 67 of them had specifically written in their notes that the findings were *suspicious for non-accidental trauma.* Of these 67 documented reports, 9 of them contained only long bone fractures. Comparing this to the second group, it can be seen that there are a total of 1,423 skeletal surveys that did not mention *suspicious for non-accidental trauma* in their reports. Of these, 177 of them had findings of long bone fractures without any other findings. Comparing these two sets of data shows that there is not a statistically significant difference between the two groups (p-value 0.85)

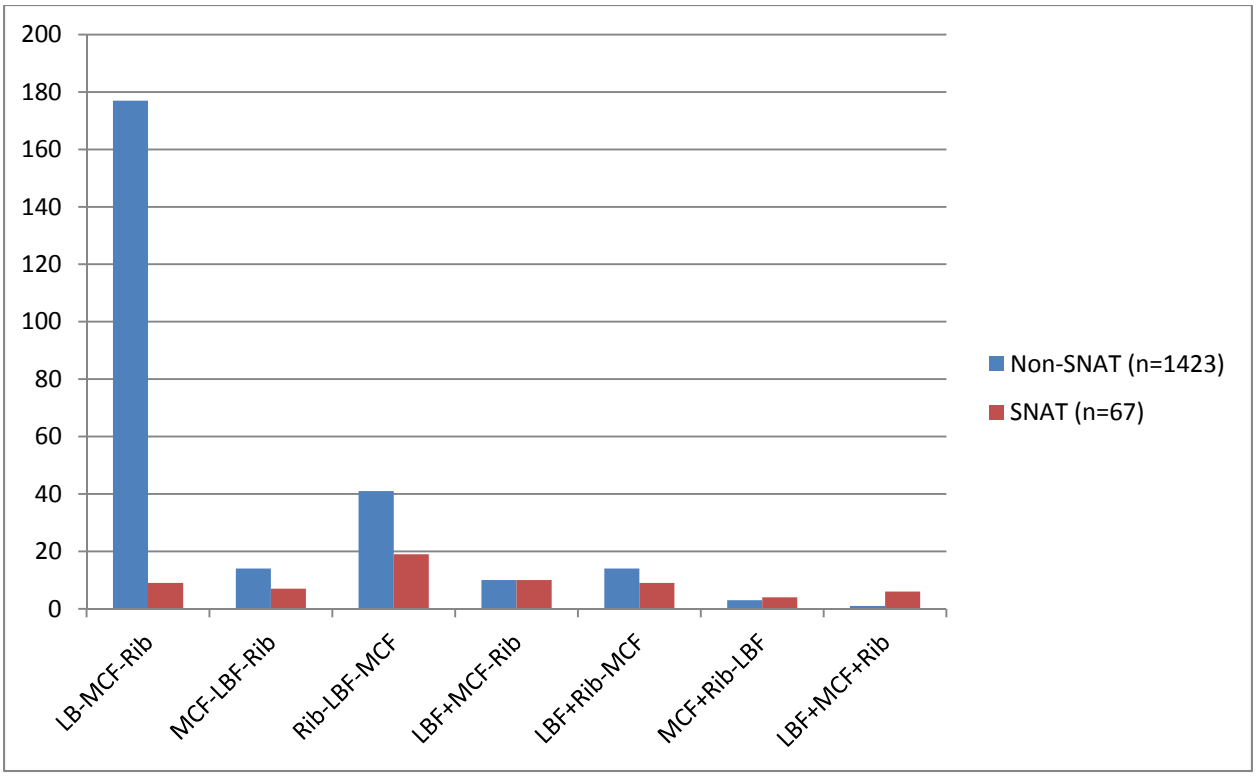

Figure 1: A visual description of Table 1 showing the quantity of fractures categorized for SNAT and non-SNAT. This is simply a visual description of the types of fractures observed, but it also demonstrates which fractures warrant a SNAT report. For example, a long bone fracture only without a metaphyseal corner fracture or rib fracture should not warrant a SNAT report. This is also seen visually in the first row which shows substantially more non-SNAT reports with LB fractures vs those which contained SNAT. Comparing this to the last row which has LBF+MCF+Rib fractures, it can be seen that most of the reports that contained these fractures stated SNAT, there was only one report which did not.

Discussion

As shown in Table 1, there appears to be a significant difference in reporting of *non-accidental trauma* amongst radiologists, even amongst fractures that are highly suspicious for abuse. Table 1 shows several combinations of fractures. Using the first row as an example, it can be seen that of the 1,490 skeletal surveys examined, 186 of them had only long bone fractures. Of the 1,490 skeletal surveys, 67 of them had specifically written in their notes that the findings were *suspicious for non-accidental trauma.* Of these 67 documented reports, 9 of them contained only long bone fractures. This means that the radiologist who read the film noted that there was only long bone fractures present and based on this, stated clearly in the report that this was suspicious for non-accidental trauma. Comparing this to the second group, it can be seen that there are a total of 1,423 skeletal surveys that did not mention *suspicious for non-accidental trauma* in their reports. Of these, 177 of them had findings of long bone fractures without any other findings. Comparing these two sets of data shows that there is not a statistically significant difference between the two groups (p-value 0.85). The *Fisher Exact Test* was used to obtain this p-value. This means that we cannot say for sure that the SNAT group was indeed correct in stating that the findings were suspicious for abuse. We cannot conclude that long bone fractures alone warrant a clearly documented phrase in the report stating that it is suspicious for abuse. It must be stated here that it is assumed that the SNAT positive group are true positives for abuse. This means that we are assuming that if the radiologist stated suspicious for non-accidental trauma (*SNAT)* somewhere in the report that the child did indeed suffer from abuse. It must be stated here that the statistical analysis and final outcomes must be re-worked for final conclusions. After analysis of the data, it appears that the Fisher Exact Test was not the most appropriate method to conduct analysis. This is further discussed in the Future Directions section.

The second row looks at reports that are SNAT positive and have metaphyseal corner fractures (MCF) present as their only findings and compares them to skeletal surveys that do not mention SNAT and have MCFs present as their only findings. It can be seen that of the 67 SNAT positive reports, 7 of them contained only MCFs. Of the 1,423 reports that did not

mention SNAT, 14 of them contained only MCFs. These two groups are statistically different as shown by the p-value comparing them. Based on this, it can be concluded that the group that did not mention SNAT in their report, should have. This conclusion is based on the assumption that the radiologist who mentioned SNAT in their reports were indeed correct and that the child was abused. Again, it assumes 100% sensitivity and specificity in the SNAT positive group. This is further discussed in the *future direction* section. The remaining five categories of fractures all appear to be statistically significant when comparing the two groups. It appears that a child with a metaphyseal corner fracture, a rib fractures, or the combination of any of these with a long bone fracture, should merit a note that these findings are suspicious for non-accidental trauma somewhere in the report. Again, the statistical analysis was incorrect after further analysis and this will be further discussed in the Future Directions section.

As shown in the last row, there were a total of 7 skeletal survey reports which contained long bone fractures, rib fractures, and metaphyseal corner fractures. Of these seven, 6 of them specifically mentioned in their report findings that this was suspicious for non-accidental trauma. There appears to be 1 case where the child suffered from multiple fractures: long bone, rib, and corner fractures, but the report did not mention that this is suspicious for non-accidental trauma. This type of finding epitomizes the idea behind this project. As stated in the introduction, multiple fractures increase the likelihood of abuse four to six fold. These fractures are the most specific for abuse, which makes the case more likely to have been abusive. Several questions can arise from this case alone. What did the primary care physician do with the skeletal survey report findings? Did they understand the significance of the fractures? How urgent did the clinician feel the situation was to remove the child from the care givers home? And ultimately, what happened to the child?

The combination of all these factors is why we propose to have a standardized reporting system for likelihood of abusive fractures. We propose a Skeletal Survey – Reporting and Data System (SS-RADS) score which will help guide clinicians in their management of non-accidental trauma causes. We propose a SS-RADS score ranging from zero to five. A score of zero indicates an incomplete skeletal survey study. A score of 1 suggests a negative skeletal survey with no

fractures. A score of 2 suggests benign findings. A score of 3 suggests probably benign findings. A score of 4 suggests a suspicious abnormality. A score of 5 suggests a highly suspicious skeletal survey abnormality that requires immediate action.

As an example, imagine a two year old child comes in for a routine check up and the clinician suspects abuse and orders a skeletal survey which ultimately shows a single healing right digit fracture; a SS-RADS score of 2 can be given. This tells the primary care physician that the finding is benign and makes them less concerned for abuse. On the other hand, if the same two year old child comes in and this time the skeletal survey shows multiple healing rib fractures, long bone fractures, and corner fractures, a SS-RADS score of 5 would be given. This score can help guide the clinician in making the appropriate decision and reporting the case to CPS and removing the child from the care givers home.

The data obtained in this initial report supports the hypothesis that radiologists are not consistent with their reporting of non-accidental traumas in skeletal surveys which contain multiple fractures. This means that although the types of fractures are listed in the reports, the interpretation of these fractures is left to the primary care physician. It has yet to be determined how much the average primary care clinician understands the significance of these fractures. A standardized reporting system would help eliminate this inconsistency and ambiguity in skeletal survey reports. This preliminary set of data is by no means complete and will require extensive additional research to support these claims, but it does provide a foundation for which additional research can be built on.

Future Directions

The preliminary set of data obtained in this paper is a stepping stone for a bigger project in the future. There are several assumptions that were presumed in this paper that must be validated before the conclusions can be proven factual. As stated in the discussion, a major assumption made during the analysis of the data was that the 67 cases which contained the phrase *suspicious for non-accidental trauma* in the report were in fact all true abusive fractures. This assumption was necessary to make so that the data between the two groups can be compared, but is in all likelihood incorrect. For example, it has already been proven that a metaphyseal corner fracture is not 100% specific or sensitive for abuse, but this project assumes that it is. In order to get a more accurate picture of which fractures were true abusive fractures secondary to a caregiver, an entire separate project must be conducted at the legal level. This project would require that the patients with suspicious fractures in each data set be followed up and see what the outcome of each case was. This would be a major step in deciding which fractures ultimately led to CPS involvement and ultimately, proven to be abusive fractures. Once this is completed, another retrospective analysis can be done to see which fractures lead to proven abuse cases at the legal level and which ones are more ambiguous. An analysis can be completed to also check which types of fractures are often overturned secondary to fractures being caused by bone disease and not fractures. Finally, once this is completed, another research project can be conducted to determine whether the SS-RADS score is accurate in predicting abuse. The combination of these studies would take years, but the potential for improved outcomes in our pediatric population might be well worth it.

Another direction of research that would be of benefit to this project would be to determine how much the average primary care understands the significance of certain fractures. It might be very possible that the majority of clinicians do not need a standardized reporting system to help them interpret that '*multiple corner fractures*' is highly suspicious of abuse. If this were the case, then the idea of a standardized reporting system would be completely unnecessary. This type of research would be easily conducted by handing out

sample skeletal survey reports to clinicians and having them fill out a questionnaire to determine how well they understand the findings in the report.

Another possible project that can be done using the data set in this study would be to compare readings amongst specific radiologist. As stated in the methods section, the data set in this project contains the name of the radiologist who read the skeletal survey and wrote the report. An analysis can be done to determine if there was a difference in reporting amongst these radiologists. Were the majority of SNAT positive reports written by the same radiologist? Was there a radiologist that called one type of fracture non-accidental in one report, then left the fracture unnamed in another? This type of data would help support or disprove the notion that a standardized reporting system is necessary.

There were parts of the data that were not included in the final analysis that should have been. For example, the data set collected included more than just long bone fractures, metaphyseal corner fractures, and rib fractures. There were several skull fractures and healing fractures that also are suspicious for non-accidental trauma. These were not considered in the analysis, but they were included in several of the reports that ultimately were labeled as suspicious for non-accidental trauma. A more thorough project can be conducted which looks at all of the data set and compares their end results. Additionally, the Fisher Exact Test was utilized to compare the data and obtain the stated p-values. An evaluation of this test must be conducted to check if it is accurate in the application to the data set.

Finally, for a more accurate depiction of which cases are suspicious for abuse, the fractures should be documented more descriptively. For example, in the data set, long bone fractures were documented, but it was not specified whether the fractures were multiple, bilateral, or single. As mentioned in the introduction, bilateral long bone fractures are more specific for abuse. By being more specific in the types of fractures, more accurate results for SNAT would be obtained in the end. This project would require re-reading all the reports which contained long bone fractures and re-documenting their findings to be more specific.

Conclusion

From this preliminary set of data, it can be concluded that discrepancies exist in the reporting of non-accidental traumas in radiological skeletal survey surveys. Of the fractures analyzed in this report, it appears that a difference in reporting in SNAT was observed in any combination of long bone fractures, metaphyseal corner fractures, and rib fracture (excluding long bone fractures only). We propose a Skeletal Survey – Reporting and Data System (SS-RADS) score which will help guide clinicians in their management of non-accidental trauma cases and help radiologist in standardizing their reporting methods. This reporting system will help improve how radiologist report findings in skeletal surveys which will eliminate the clinicians need to interpret the results.

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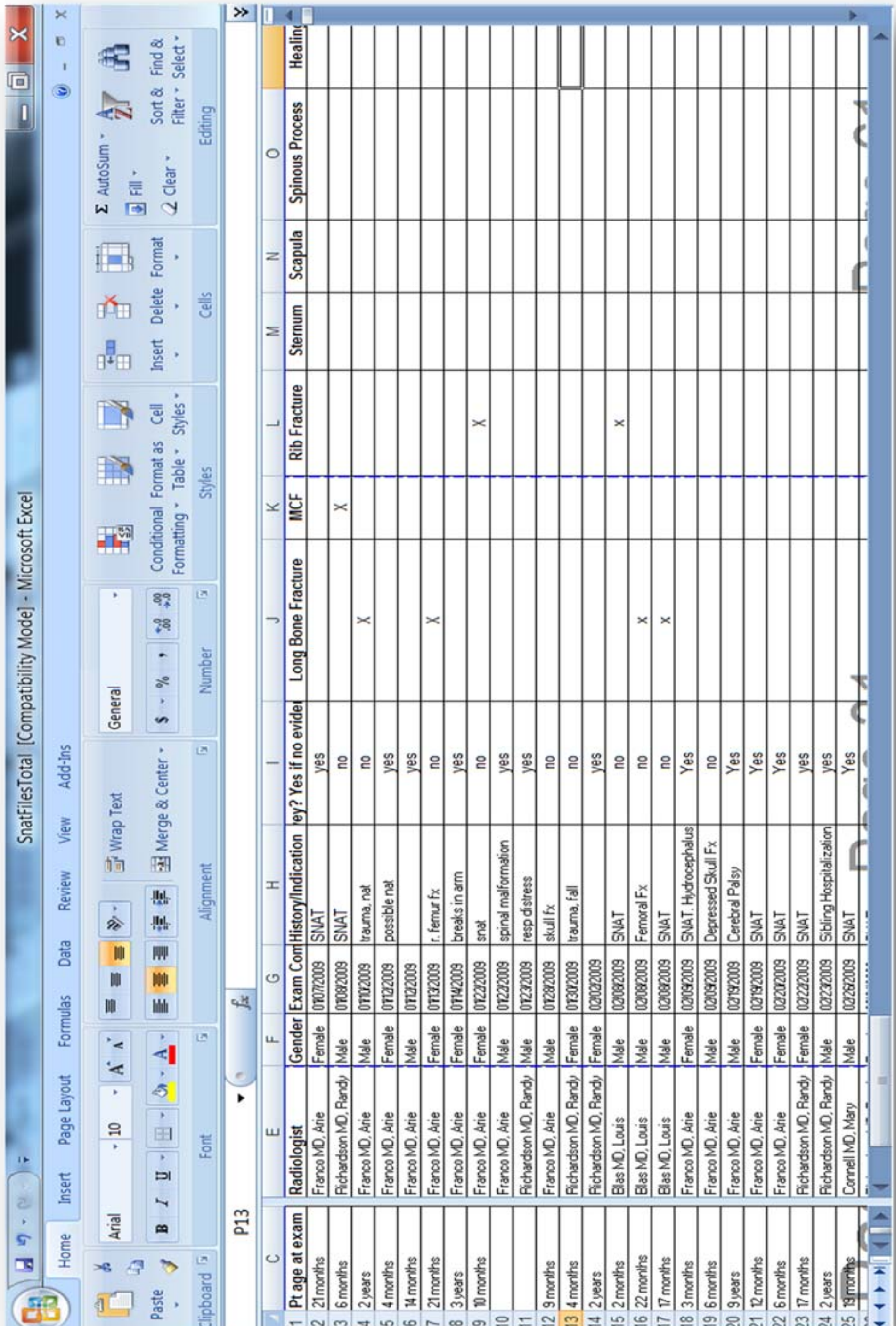

	C	E	F	G	H	I	J	K	L	M	N	O	
1	Pt age at exam	Radiologist	Gender	Exam Com	History/Indication	ey? Yes if no evider	Long Bone Fracture	MCF	Rib Fracture	Sternum	Scapula	Spinous Process	Healin
2	21 months	Franco MD, Arie	Female	01/07/2009	SNAT	yes							
3	6 months	Richardson MD, Randy	Male	01/08/2009	SNAT	no		X					
4	2 years	Franco MD, Arie	Male	01/10/2009	trauma, nat	no	X						
5	4 months	Franco MD, Arie	Female	01/12/2009	possible nat	yes							
6	14 months	Franco MD, Arie	Male	01/12/2009		yes							
7	21 months	Franco MD, Arie	Female	01/13/2009	r. femur fx	no	X						
8	3 years	Franco MD, Arie	Female	01/14/2009	breaks in arm	yes							
9	10 months	Franco MD, Arie	Female	01/22/2009	snat	no			X				
10		Franco MD, Arie	Male	01/22/2009	spinal malformation	yes							
11		Richardson MD, Randy	Male	01/23/2009	resp distress	yes							
12	9 months	Franco MD, Arie	Male	01/28/2009	skull fx	no							
13	4 months	Richardson MD, Randy	Female	01/30/2009	trauma, fall	no							
14	2 years	Richardson MD, Randy	Female	02/02/2009		yes							
15	2 months	Blas MD, Louis	Male	02/08/2009	SNAT	no			x				
16	22 months	Blas MD, Louis	Male	02/08/2009	Femoral Fx	no	x						
17	17 months	Blas MD, Louis	Male	02/08/2009	SNAT	no	x						
18	3 months	Franco MD, Arie	Female	02/09/2009	SNAT. Hydrocephalus	Yes							
19	6 months	Franco MD, Arie	Male	02/09/2009	Depressed Skull Fx	no							
20	9 years	Franco MD, Arie	Male	02/19/2009	Cerebral Palsy	Yes							
21	12 months	Franco MD, Arie	Female	02/19/2009	SNAT	Yes							
22	6 months	Franco MD, Arie	Female	02/20/2009	SNAT	Yes							
23	17 months	Richardson MD, Randy	Female	02/22/2009	SNAT	yes							
24	2 years	Richardson MD, Randy	Male	02/23/2009	Sibling Hospitalization	yes							
25	19 months	Connell MD, Mary	Male	02/26/2009	SNAT	Yes							

Appendix 1: Screen shot of data set collection.