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# Pediatric Radiology

## Diagnostic yield of double reading initial skeletal surveys versus follow-up skeletal surveys for suspected child physical abuse

--Manuscript Draft--

<b>Manuscript Number:</b>	PRAD-D-18-00527
<b>Full Title:</b>	Diagnostic yield of double reading initial skeletal surveys versus follow-up skeletal surveys for suspected child physical abuse
<b>Article Type:</b>	Original Article
<b>Abstract:</b>	<p><b>Background</b> Follow-up skeletal surveys (FUSS) are performed in cases of suspected child physical abuse. However, the yield of FUSS compared to double-reading initial skeletal surveys (SS) is not known.</p> <p><b>Objective</b> To compare the diagnostic yield of FUSS performed for suspected child abuse to double reading initial exams.</p> <p><b>Materials and methods</b> All initial SS performed between 2/2/2013-3/23/2015 for suspected physical abuse were double-read. McNemar test was applied to compare: 1) yield of FUSS after only single reading versus double reading initial SS; 2) yield of FUSS after only single reading initial SS versus the yield of FUSS after double reading initial SS.</p> <p><b>Results</b> During the study period, 1056 initial SS were performed (M:F=617:439; age range=2 days-9 years; IQR=4-18 months). Of 293/1056 (28%) cases with FUSS, double reading initial SS showed 30/293 (10%) additional findings. FUSS showed additional findings in 32/263 (12%) not identified by double reading. The difference between the diagnostic yield of FUSS (62/293, 21%) compared to double reading (30/293, 10%) was significant, <math>p &lt; 0.0001</math>. Similarly, the difference between the diagnostic yield of FUSS after only single reading initial SS (62/293, 21%) compared to the diagnostic yield of FUSS after double reading (37/293, 13%) was also significant, <math>p &lt; 0.0001</math>.</p> <p><b>Conclusion</b> FUSS identified significantly more new findings than double reading initial SS. However, double reading before performing FUSS significantly decreased the yield of the FUSS. These results show the benefit of double reading and the need for further research to determine if double reading initial SS can obviate follow-up exams in select cases.</p>

1 Original article

2 **Diagnostic yield of double reading initial skeletal surveys versus follow-up**  
3 **skeletal surveys for suspected child physical abuse**

4  
5 **Abstract**

6 **Background** Follow-up skeletal surveys (FUSS) are performed in cases of suspected child  
7 physical abuse. However, the yield of FUSS compared to double-reading initial skeletal surveys  
8 (SS) is not known.

9 **Objective** To compare the diagnostic yield of FUSS performed for suspected child abuse to  
10 double reading initial exams.

11 **Materials and methods** All initial SS performed between 2/2/2013-3/23/2015 for suspected  
12 physical abuse were double-read. McNemar test was applied to compare: 1) yield of FUSS after  
13 only single reading versus double reading initial SS; 2) yield of FUSS after only single reading  
14 initial SS versus the yield of FUSS after double reading initial SS.

15 **Results** During the study period, 1056 initial SS were performed (M:F=617:439; age range=2  
16 days-9 years; IQR=4-18 months). Of 293/1056 (28%) cases with FUSS, double reading initial SS  
17 showed 30/293 (10%) additional findings. FUSS showed additional findings in 32/263 (12%) not  
18 identified by double reading. The difference between the diagnostic yield of FUSS (62/293, 21%)  
19 compared to double reading (30/293, 10%) was significant,  $p<0.0001$ . Similarly, the difference  
20 between the diagnostic yield of FUSS after only single reading initial SS (62/293, 21%)  
21 compared to the diagnostic yield of FUSS after double reading (37/293, 13%) was also  
22 significant,  $p<0.0001$ .

23 **Conclusion** FUSS identified significantly more new findings than double reading initial SS.  
24 However, double reading before performing FUSS significantly decreased the yield of the FUSS.  
25 These results show the benefit of double reading and the need for further research to determine if  
26 double reading initial SS can obviate follow-up exams in select cases.

27

## 28 **Introduction**

29 Child physical abuse is a leading cause of traumatic injury in United States children. In  
30 2016 alone, 123,032 U.S. children were documented victims of physical abuse and 639 died as a  
31 consequence [1]. Survivors of physical child abuse often suffer long-term consequences. Studies  
32 have shown that physically abused children are more prone to physical and mental health  
33 conditions as adults including depression and drug abuse, as well as premature mortality [2-5].  
34 Because of the magnitude of this problem and its life altering consequences, early recognition  
35 and correct diagnosis of physical abuse is essential. Failure to do so can result in a child  
36 returning to a hostile environment, putting him or her at risk for repeat injury [6, 7].

37 Accurate diagnosis of physical abuse is not straightforward. More than 80% of children  
38 affected are under the age of 18 months and therefore cannot express themselves verbally [8]. In  
39 addition, victims often do not have external signs of trauma [9, 10]. One third to half of  
40 radiologically detected fractures are clinically occult [11, 12]. Consequently, the American  
41 College of Radiology recommends that clinicians order skeletal surveys for any child less than  
42 24 months of age in whom physical abuse is suspected, as well as a follow-up skeletal survey  
43 two weeks later if the initial exam is abnormal to evaluate for signs of healing at known and  
44 previously undetected fracture sites [13].

45 Multiple studies have shown that follow-up skeletal surveys can improve diagnostic yield  
46 by identifying additional fractures and adding other helpful information such as fracture age [10,  
47 14-16] . We hypothesize that in many cases, additional findings on follow-up skeletal surveys are  
48 not new but were in fact present and detectable on the initial skeletal survey. The purpose of this  
49 study is to compare the diagnostic yield of follow-up skeletal surveys performed for suspected  
50 physical abuse to double reading initial exams.

51

## 52 **Materials and Methods**

53 Our institutional review board approved this HIPAA-compliant study and the need for  
54 written informed consent was waived. All children who underwent a skeletal survey at our  
55 tertiary care academic pediatric hospital and affiliate facilities between February 2, 2013 and  
56 March 23, 2015 were eligible for inclusion. Patients whose skeletal surveys were performed for  
57 indications other than suspected physical abuse were excluded.

58 Skeletal surveys (initial and follow-up) were performed per our institutional protocol and  
59 included the following views: anteroposterior (AP) and lateral skull, AP chest and abdomen,  
60 lateral spine, right and left oblique ribs; bilateral AP humerus, AP forearm, PA hand, AP femur,  
61 AP tibia and fibula; and AP foot. Initial and follow-up skeletal surveys were primarily  
62 interpreted by one of 19 pediatric radiologists (2-41 years post-fellowship experience) as part of  
63 the patient's standard clinical care. Within 72 hours of single reading, initial skeletal surveys  
64 were double read by one of three non-blinded pediatric radiologists (41, 19, and 6 years post-  
65 fellowship experience). Discordant results among single readings of initial skeletal surveys,  
66 double readings of initial skeletal surveys, and follow-up skeletal surveys were adjudicated by  
67 one of three pediatric radiologists (41, 19, and 6 years post-fellowship experience). During the

68 study period, double-reading skeletal surveys was not part of our routine clinical practice, and  
69 therefore an official report of the double reading was not generated. However, discrepancies  
70 between single and double reading were communicated to both the clinical team and the initial  
71 interpreting radiologist; and radiology reports were addended as needed. Final interpretations  
72 were communicated to the ordering physician or the institutional Child Abuse Pediatrics team.

73 Patient medical records were reviewed and patient gender and age at the time of the  
74 initial skeletal survey recorded. Findings detected by single initial skeletal surveys, double  
75 reading initial skeletal surveys, and follow-up skeletal surveys were recorded and compared for  
76 each patient. Based on concordance among the interpretations, patients were designated into one  
77 of six categories as shown in Table 1. For categories 5 and 6, follow-up skeletal survey  
78 interpretations were compared to adjudicated single and double reading interpretations of the  
79 initial skeletal surveys.

80 Contingency tables were produced to address two comparisons. The first is the diagnostic  
81 yield of follow-up skeletal surveys (without double reading) compared to the diagnostic yield of  
82 double reading initial skeletal surveys (Table 2). The second is the diagnostic yield of follow-up  
83 skeletal surveys after only single reading initial skeletal surveys compared to the diagnostic yield  
84 of follow-up skeletal surveys after double reading initial skeletal surveys (Table 3). McNemar  
85 test was applied to assess statistical significance for each of these two comparisons.

86 A member of our institutional Child Abuse Pediatrics team (<BLINDED>) reviewed the  
87 electronic medical record for all patients who had findings identified on follow-up skeletal  
88 survey not identified on single reading initial skeletal surveys and subjectively determined  
89 whether or not the diagnosis of the new findings altered patient management. New findings on  
90 follow-up skeletal surveys were considered to have altered management if deemed to have

91 changed the presumed mechanism of injury, refuted an allegation of child abuse, or lead to the  
92 diagnosis of a condition that predisposed the patient to pathologic fractures (e.g. osteogenesis  
93 imperfecta).

94

## 95 **Results**

96 During the 26-month study period, 1056 children underwent an initial skeletal survey for  
97 suspected physical abuse. All 1056 children were included in this study. The mean age of this  
98 population at the time of the initial skeletal survey was 13.2 +/- 13.9 months; age range: 2 days  
99 to 9 years; median age = 9 months; interquartile range 4 - 18 months); 42% (439/1056) females.  
100 Of the 1056 children enrolled, 293 (28%) had follow-up skeletal surveys.

101 Figure 1 shows the number of patients assigned to each of the six categories from Table 1.  
102 For cases without follow-up skeletal surveys, double reading identified additional findings in  
103 21/763 (2.8%). Third readers confirmed all 21 new findings. For cases with follow-up exams,  
104 single and double readings of initial skeletal surveys were concordant in 263/293 (90%) with  
105 follow-up skeletal surveys showing no additional findings in 231/263 (88%) (Category 3) and  
106 additional findings in 32/263 (12%) (Category 4). A third reader discarded a 33<sup>rd</sup> additional  
107 fracture diagnosed on follow-up concluding the findings were not definitive. In 30/293 (10%)  
108 initial skeletal surveys, additional findings were identified by double reading that were not  
109 identified by single reading (Fig. 2 and 3). Third readers confirmed all 30 new findings. For  
110 these 30 cases, follow-up skeletal surveys showed no additional findings in 25/30 (83%)  
111 (Category 5) and additional findings in 5/30 (17%) (Category 6) not identified by either single or  
112 double reading initial skeletal surveys. Third readers confirmed all 5 new findings.

113 Table 4 shows the break down of additional findings identified on double reading and

114 follow-up exams. Correction of false positive interpretations on single reading constituted 18%  
115 (16/89) of the additional findings on double reading versus only 2% (2/89) of the additional  
116 findings on follow-up exams. Missed fractures constituted 63% (56/89) of the new findings on  
117 double reading and 94.3% (84/89) of the new findings on follow-up exams. Most of the new  
118 fractures identified both on double reading and follow-up exams were missed rib fractures, 30.4%  
119 and 41.2 % respectively.

120         The difference between the diagnostic yield of follow-up skeletal surveys after only  
121 single reading initial skeletal surveys (62/293, 21%) compared to the diagnostic yield of double  
122 reading initial skeletal surveys (30/293, 10%) was statistically significant -  $p < 0.0001$  (Table 2).  
123 Similarly, the difference between the diagnostic yield of follow-up skeletal surveys after only  
124 single reading initial skeletal surveys (62/293, 21%) compared to the diagnostic yield of follow-  
125 up skeletal surveys after double reading initial skeletal surveys (37/293, 13%) was also  
126 statistically significant -  $p < 0.0001$ ).

127         After review of the electronic medical record, it was determined that new findings  
128 identified on follow-up skeletal surveys altered management in 19% of cases (12/62) by  
129 changing the presumed mechanism of injury (9/12), refuting the allegation of child abuse (2/12),  
130 or leading to the diagnosis of osteogenesis imperfecta (1/12). Of these, 8 deemed to have altered  
131 management were not identified on either single or double reading of initial skeletal surveys  
132

### 133 **Discussion**

134         In cases of suspected physical abuse where follow-up skeletal surveys were performed,  
135 we found that double reading initial skeletal surveys showed additional findings in 10% of cases  
136 which is approximately double the percentage found by Karmazyn et al (4.5%) [17]. In

137 comparison, follow-up skeletal surveys showed additional fractures in 21% of cases. These  
138 results indicate that if choosing between double-reading initial skeletal surveys and performing  
139 follow-up skeletal surveys, follow-up skeletal surveys will maximize additional fracture  
140 identification in this patient population. However, we also found that double reading initial  
141 skeletal surveys before performing follow-up skeletal surveys significantly decreased the number  
142 of cases in which additional fractures were identified at follow-up. Therefore, these results also  
143 indicate that for a certain subset of this patient population, double reading without follow-up may  
144 be sufficient to maximize additional fracture identification.

145         The American college of Pediatrics along with the American College of Radiology  
146 recommend a follow-up skeletal survey after 10-21 days if an initial skeletal survey has  
147 abnormal findings. This recommendation is based in part on two papers authored by Zimmerman  
148 et al. and Kleinman et al. which showed that follow-up skeletal surveys added information and  
149 improved diagnostic accuracy for child abuse in 46% and 61% of cases respectively [10, 14] .  
150 Authors advocating follow-up skeletal surveys argue that these exams detect fractures not visible  
151 initially, differentiate suspected fractures from normal variants, and clarify the age of previously  
152 described fractures [14, 18] . It is also argued that follow-up skeletal surveys offer a more  
153 thorough assessment when it comes to acute rib and metaphyseal fractures, which have high  
154 specificity for abuse [10] .

155         While our study confirmed the results of prior authors that follow-up skeletal surveys  
156 detect additional fractures not identified on initial skeletal surveys, the number of additional  
157 fractures identified was significantly reduced by double reading initial exams. The time between  
158 initial and follow-up skeletal surveys can delay final disposition and create uncertainty and

159 anxiety in cases where physical abuse did not occur or potentially allow a child to remain in an  
160 unsafe environment when abusive trauma goes undiagnosed [3].

161 This study has several limitations. Of 1056 children enrolled, only 293 (28%) had follow-  
162 up skeletal surveys. A follow-up skeletal survey is ordered for all children under 36 month of age  
163 evaluated by our Child Abuse Pediatrics consult service for whom the impression is  
164 indeterminate or concerning for abuse. Those children with a history that is plausible as an  
165 accidental mechanism of injury do not have clinic follow up.

166 We do not know the reason why the follow-up skeletal surveys were performed in some  
167 cases. This introduces a selection bias as the fracture yield of double reading initial skeletal  
168 surveys for cases with follow-up skeletal surveys was 10% compared to 2.8% for cases without  
169 follow-up skeletal surveys. The effect of double reading and follow-up skeletal surveys on  
170 reader confidence was not assessed. It may be that one or both of these techniques not only  
171 increased the number of fractures detected but also increased the diagnostic confidence of the  
172 interpreting radiologist. Finally, we did not assess the effect of follow-up skeletal surveys on  
173 determining fracture age.

174

## 175 **Conclusion**

176 Follow-up skeletal surveys were significantly better at identifying new fractures compared to  
177 double reading initial skeletal surveys in cases of suspected physical abuse. However, double-  
178 reading initial skeletal surveys before performing follow-up exams significantly decreased the  
179 yield of the follow-up skeletal surveys indicating that these techniques may be complementary.  
180 These results show the value of double-reading initial skeletal surveys and indicate the need for

181 further investigation to determine if double reading initial skeletal surveys can obviate the need  
182 for follow-up exams in select cases.

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232

### 233 **Legends**

234 **Fig. 1** Distribution of the patients among the six concordance categories

235 **Fig. 2** 2-year-old boy with suspected child physical abuse. Frontal radiograph of the left tibia  
236 and fibula shows periosteal reaction at the mid tibia (black arrow) and nondisplaced distal tibial  
237 fracture (white arrow) that were missed on single reading but identified at double reading

238 **Fig. 3** 2-months-old girl with suspected child physical abuse. AP left tibia/fibula radiographs (A:  
239 initial exam and B: follow up exam) show a missed subphyseal metaphysis fracture of the  
240 proximal tibia (white arrow) that was missed on the initial skeletal survey after single and double  
241 reading but identified on the follow up exam

242

243 **Table 1.** Six categories reflecting the concordance among single readings of initial skeletal surveys, double readings  
 244 of initial skeletal surveys, and follow up skeletal surveys

Category	Single and double readings of initial skeletal survey	Initial and follow-up skeletal surveys
1	Concordant	Not Performed
2	Discordant	Not Performed
3	Concordant	Concordant
4	Concordant	New findings at follow-up
5	Discordant	Concordant
6	Discordant	New findings at follow-up

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**Table 2.** Contingency table for comparing the diagnostic yield of follow-up skeletal surveys versus the diagnostic yield of double reading initial skeletal surveys

		Additional findings on double reading	
		No	Yes
Additional findings on follow-up (without double-reading)	No	231 (Category 3)	0

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	Yes	32 (Category 4)	30 (Category 5-6)
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275 **Table 3.** Contingency table for comparing the diagnostic yield of follow-up skeletal surveys after only single reading  
 276 initial skeletal surveys versus the diagnostic yield of follow-up skeletal surveys after both double reading initial  
 277 skeletal surveys  
 278

		Additional findings on follow-up after double reading	
		No	Yes
Additional findings on follow-up after single reading only	No	231 (Category 3)	0
	Yes	25 (Category 5)	37 (Category 4,6)

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283 **Table 4.** The number of patients with additional findings identified on double reading and follow up exams per type  
 284 of finding.  
 285

		Number of patients with additional findings identified on:	
		Double reading initial exams	Follow up exams
Fractures	Ribs	8 (17)*	16 (35)*
	Metacarpals/phalanges	3 (3)*	3 (9)*
	Metatarsals/phalanges	6 (14)*	3 (8)*
	Long bones	6 (12)*	18 (27)*
	Acromion/clavicles	1 (1)*	2 (3)*
	Vertebral bodies	1 (3)*	2 (2)*
	Skull fractures	5 (6)*	0
Osteoporosis		6	2
Wide sutures		4	1
Bulging fontanel		2	0
Acuity		1	0
Failure to thrive		4	0
False positives/overcall		12 (16)*	2
Total		59 (89)*	49 (89)*

286  
 287 (\*) is the total number of additional findings identified.  
 288







