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Title:

The use of a radiolucent template to improve bone age X-ray quality (BASIC study)

Running or short title:

Bone Age Study In Children (BASIC Study)

T G Cockill[1], A Hewitt[2], C Heafey[2], N P Wright[2], C J Elder[1,2]

[1]University of Sheffield, Sheffield, UK

[2]Sheffield Children's NHS Foundation Trust, Sheffield, UK

Corresponding Author:

Dr Charlotte Elder

Academic Clinical Lecturer in Paediatrics,

Academic Unit of Child Health,

Sheffield Children's Hospital

Western Bank

Sheffield

S10 2TH

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Abstract

Background: Left hand and wrist X-rays are conventionally used to assess skeletal maturity using methods such as Tanner-Whitehouse3 (TW3). We noted a number were poor quality, caused by difficulty with hand placement. We introduced a simple radiolucent hand template to assist in hand positioning and assessed changes in X-ray quality and repeat X-ray rates.

Method: The position of fingers, thumb and overall clarity of bone age X-rays were prospectively scored. In the absence of a validated tool to assess quality a 1-3 scale (poor, borderline, good) was devised. A radiolucent hand template was introduced for use in the intervention group. Need for repeat X-ray was determined by set criteria.

Results: The intervention improved scores. More patients scored 3 (good) for positioning of fingers (89.29% and 85.33%, p=0.38), thumb (98.21% and 89.96%, p=0.06) and overall clarity (76.79% and 70.27%, p=0.41) for the intervention (N=56) and control groups (N=259) respectively. No patient required repeat X-ray from the intervention group, compared with 28 in the control group (p=0.007).

Discussion: Achieving good quality bone age X-rays is more difficult than previously assumed. The use of a radiolucent hand template has been shown to improve hand position and significantly reduce the need for repeat X-ray.

Introduction

Bone age studies traditionally require X-ray of the left hand and wrist to assess skeletal maturity. The Tanner-Whitehouse 3 (TW3) scoring method provides an objective framework for calculating bone age and specifies exact placement of the hand.[1]

In our service we have noted a number of poor quality films caused by difficulty with hand placement, e.g. scrunching of the fingers. This compromises the ability to score the X-rays accurately and can necessitate repeat X-ray with the associated inconvenience for the patient, increased radiation exposure and financial implications.

We introduced a simple radiolucent hand template to which the patient could match their hand in order to assist positioning (*figure 1*). Three separate hand template sizes were devised to accommodate for the variety of patient ages and hand sizes.

Figure 1, Radiolucent hand template (with and without hand).

The aim of the study was to assess changes in X-ray quality through objectively analysing the positioning of fingers and thumb and clarity of X-ray. The need for repeat X-ray was similarly assessed to determine if repeat X-ray rates could be reduced.

Patients and Methods

Study Design

This was a prospective intervention study. A service evaluation of the quality of bone age X-rays was conducted from June 2013 to February 2014. This information was then used as control data against which our hand template intervention was measured. The study period commenced in March 2014 and ran to March 2015, during which all consented individuals used the template.

All bone age X-rays during the study period were evaluated by a single Auxology Nurse blinded as to whether or not the template had been used. To evaluate the effectiveness of the intervention, all bone age X-rays were scored against set criteria. Due to the absence of a validated tool, the position of fingers, thumb and overall clarity of bone age X-rays were scored by a simple 1-3 scale (poor, borderline, good), devised in conjunction with an academic radiologist.

Primary outcome measure

Following introduction of the hand template the degree of improvement in quality of bone age X-rays was objectively assessed using the simple scale outlined above. A reduction of 5% of X-rays scoring borderline or poor in each category was felt to indicate clinically significant improvement.

Secondary outcome measure

In addition, an evaluation of the effect the intervention had on repeat X-ray rates was made. Pre-intervention data demonstrated an 11% repeat X-ray rate due to poor quality films as a

result of suboptimal hand placement. When X-rays were judged by the auxology nurse to be of insufficient quality to enable accurate scoring, the family was contacted and a repeat X-ray request made.

In the intervention cohort, the need for repeat X-ray was determined by criteria set by the auxology nurse as follows:

1. X-ray whose score for either finger positioning or clarity was equal to 1 (poor quality).
2. X-ray where the thumb positioning scored 2 (borderline quality) with an overall aggregate score of 7 or less (i.e. where any of the other categories scored <3). Thumb positioning was deemed the most important criteria when scoring bone age X-rays using the TW3 method and was most commonly linked with a need to repeat X-ray in practice.

Patients

Patients were recruited if they were undergoing a bone age X-ray as part of their routine management in the growth and endocrine clinic at a single centre, Sheffield Children's Hospital, UK. Children and young people were aged between 0 and 20 years of age. The control arm data were derived from patients who had formed part of the service evaluation.

Exclusion criteria:

- Study materials were not translated into multiple languages therefore patients were only recruited if their English was deemed of a standard to ensure informed consent.
- Any child with a left hand abnormality causing difficulty in placing their hand flat e.g. contractures.

- Children with an inadequate level of understanding to comply with the instructions required to match their hand to the outline placed on the X-ray plate.

The study was approved by Yorkshire and Humber Research Ethics Committee. Written informed consent was given by all participants. This study complies with the World Medical Association Declaration of Helsinki regarding ethical conduct of research involving human subjects.

Results

Study population

There were 259 children in the initial service evaluation (123 female) aged between 1.92 to 18.48 years (mean 10.21 years). The intervention arm comprised 56 participants (28 female) ranging from 0.9 to 15.77 years (mean 8.95 years). The groups were equally matched for gender however the intervention group were younger (p=0.03) (*table 1)*. All P values in this study were calculated using Fisher's exact test.

Table 1, Study population age profile

Quality of bone age X-rays

The intervention improved X-ray quality scores. Fewer patients scored less than 3 for the position of fingers (10.7% and 14.7%, p=0.38), thumb (1.8% and 10.0%, p=0.06) and overall clarity (23.2% and 29.7%, p=0.41) for the intervention and control groups respectively (*figure*

2~~graph 1~~). This equates to an improvement of 3.7% for positioning of fingers, 8.3% for positioning of thumb and 6.5% for overall clarity.

Figure 2, X-ray quality scores.

Repeat X-ray rates

The template significantly reduced the numbers requiring repeat X-ray. No patient required a repeat X-ray from the intervention group, compared to 28 (10.81%) in the control group (p=0.007).

Limitations

Due to the nature of bone age X-rays and their appropriate indication, we were only able to obtain a small number of patients aged 15.00-19.99 years old. This is unlikely to adversely affect the significance of this study in the context of such a simple and cheap intervention that can be seen to have a greater impact on those younger users. This is illustrated in the figure below (*figure 3)* which shows the percentage of patients in each age group with a net X-ray score that qualified as either 'poor', 'borderline' or 'good'. It can be seen that in the 0-4.99 age range, the percentage of net scores that were 'good' increased from 72.2% to 100%; whilst in the 5-9.99 age range, this increased from 84.5% to 96.7%.

Figure 3, Percentage net X-ray score by age group.

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Discussion

Achieving good quality films for bone age studies is important for the optimal assessment of skeletal maturity. The data in this study suggest that achieving this may be more difficult than previously assumed.

The use of a simple radiolucent hand template to which children and young people can match their hand significantly improved the positioning of the hand and the clarity of the X-rays produced. This improvement may be due to the increased likelihood of the patient positioning their hand in such a way as to more closely reflect the ideal positioning described by Tanner[1], enhanced awareness by both the radiographer and child about accurate hand placement and a greater chance that the child will keep their hand still as the X-ray is taken.

The need for repeat X-ray was eliminated in this study. Given that the radiation dose of a bone age X-ray is quantified as 0.0001mSv (0.1 microSieverts)[2], this represents an important reduction in radiation exposure.

The results of this study support the introduction of this simple and cost-effective intervention. The implementation of such a simple and safe intervention has been shown to significantly reduce the need for repeat X-ray in those patients who require bone age X-rays.

Acknowledgements

We would like to thank the patients and their parents who agreed to take part in this study and Dr Offiah for her advice on the scoring of X-rays.

Disclosure Statement

The authors have nothing to disclose.

References

1. Tanner J M, Healy M, Goldstein H, *et al.* Assessment of skeletal maturity and prediction of adult height (TW3 Method), 3rd edn. London: WB Saunders, Harcourt Publishers Ltd, 2001.
2. Huda W, Gkanatsios NA, Radiation dosimetry for extremity radiographs. Health Phys 1998;75;492-999.

Figures

Figure 1, Radiolucent hand template (with and without hand).

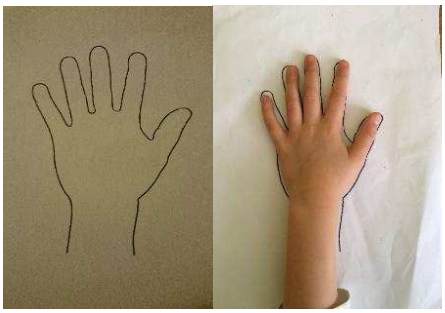

Table 1, Study population age profile

	Age range (years)	**0-5**	**5.01-10**	**10.01-15**	**15.01-20**	**Total**	**Mean**	**SD**
Control	1.92-18.48	18	109	106	26	259	10.21	3.87
Intervention	0.9-15.77	7	30	16	3	56	8.95	3.46

Figure 2, X-ray quality scores.

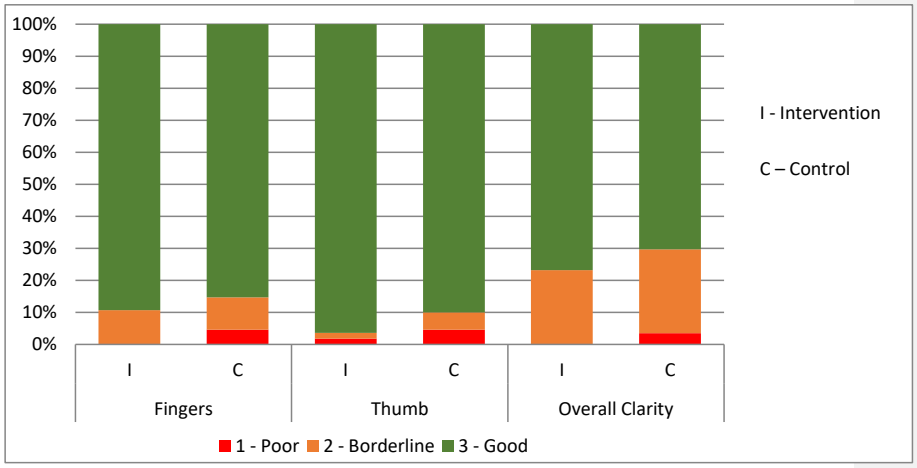

Figure 3, Percentage net X-ray score by age group