*Title Page (with author details)

Skeletal survey quality in non-accidental injury – a single site evaluation of the effects of imaging checklists

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Abstract

Aims: Evidence suggests ongoing practice variability in the quality of skeletal survey examinations for non-accidental injury. The purpose of the study was to investigate the effects on examination quality following the implementation of imaging checklists.

Method: A retrospective evaluation of skeletal survey examinations was carried out on studies performed between January 2007 and November 2014 at a large District General Hospital Trust. Longitudinal assessment was undertaken over three periods, before and following the introduction of two versions of imaging checklists, following modifications. Examinations were assessed and scored using three measures for completeness and quality employing a modified established scoring system against a professional body national standards document.

Results: A total of 121 examinations met the inclusion criteria, all quality assessment measures showed improvements between each period. Examination completeness increased from median of 13 projections, to 20 throughout the three periods. Mann Whitney *u* Tests showed significant differences between each period. The mean combined anatomy score reduced from 3.11 to 1.10 throughout the three periods. Independent *t* Tests and Mann Whitney *u* Tests showed a significant decrease throughout the study period. Total percentage examination quality increased from median 44% - 83% throughout the three periods. Independent *t* Tests also showed significant differences between each period.

Conclusion: The use of imaging checklists to improve quality and to support the optimal acquisition of the non-accidental injury skeletal survey shows encouraging results. However, further work is needed to optimise content and the use of checklists in practice.

***Highlights (for review)**

Highlights

Skeletal survey examinations for non-accidental practices have been shown to vary in content and in quality.

Checklists have demonstrated improvements in compliance to guidelines for tasks across health disciplines and in a variety of settings.

Practice was assessed following the introduction of imaging checklists using a modified established scoring system against a professional body national standards document.

Improvement in the content and quality were observed in all three measures.

Imaging checklists demonstrated improvements to skeletal survey examination content and quality.

Keywords

Skeletal survey

Non-accidental injury

Checklists.

Skeletal survey quality in non-accidental injury – a single site evaluation of the effects of imaging checklists

Introduction

The management of children with suspected non-accidental injury (NAI) continues to challenge healthcare and society.[1] In the United Kingdom (UK), the number of children subject to a child protection plan has increased from 34,100 in 2008 to 62,200 in 2015.[2] Media reporting has both increased rates of medical and social services referrals and also increased the detection of NAI.[3] Although referral rates have increased, under-reporting is still a recognised problem; one third of abused children had a previous medical contact in which signs of NAI were evident, but not recognised.[4] Under-reporting[5] and variations in adherence to referral guidelines[6] have also been highlighted as problems in the management of NAI.

Skeletal surveys are widely regarded as the primary investigation tool for the evaluation of NAI in children.[7-9] Up to half of injuries detected during skeletal survey imaging are not evident clinically.[9] The Royal College of Radiologists (RCR) and the Royal College of Paediatrics and Child Health (RCPCH) have jointly set out the necessary referral, imaging acquisition and communication of findings required when NAI is suspected.[10] The standard required and radiographic projections are set out in detail.

Offiah and Hall[11] retrospectively assessed 50 skeletal surveys and identified significant variation in their content and quality. They found that none complied with the draft guidelines by the British Society of Paediatric Radiologists (BSPR). These were almost identical to the RCR / RCPCH guidelines from 2008 and called for, "…the development and dissemination of definitive national guidelines."[11] Using a questionnaire approach others found similar significant variations in skeletal survey national practice.[12] In a follow-up study to Offiah and Hall, Swinson et al.[13] adapting their methodology, found improvements in skeletal survey quality and attributed it to the BSPR guidelines, although they still observed considerable variation in standard.

In the last decade safety checklists have been introduced into the healthcare environment in an attempt to reduce adverse events and improve patient safety, particularly in the operating theatre environment.[14] Similar to those used in the military, aviation industry and manufacturing, the World Health Organisation (WHO) launched the 'Surgical Safety Checklist' in 2008.[15] The WHO checklist system is currently used in 1790 institutions worldwide, with active interest shown by a further 4132.[16] Systematic review and meta-analysis data of the effects of the Surgical Safety Checklist on post-operative complication rates show encouraging results.[17]

The research has consistently shown a lack of a unified approach to imaging protocols for NAI and, specifically, deficiencies in quality of the skeletal survey examinations. The implementation and development of definitive national guidelines have contributed to improvements; however there are still widespread variations in practice. Having shown encouraging results in other areas of healthcare practice, this study explored the effects of checklists on skeletal survey practice and quality. The aims of this study were to; evaluate the effects of checklists on skeletal survey practice and quality, to inform the discussion on methods for improving detection rates for NAI.

Method

A retrospective analysis of 121 skeletal surveys was performed that were undertaken between January 2007 and November 2014 at a single, two site district general hospital trust. As part of ongoing local audit process to improve skeletal survey quality a checklist similar to the WHO surgical checklist[18] was introduced and modified. The required projections and reminders of the necessary documentation were included in the checklist. The first checklist was introduced in September 2008 and modified in October 2012, as part of the recommendations from the previous audit process. Hence comparative analyses were undertaken of examination quality; before checklist introduction (January 2007 – September 2008), after checklist version one (September 2008 – October 2012) and after checklist version two (October 2012 – November 2014). Skeletal survey checklist version two is shown in Figure 1. Before checklist introduction – period one, checklist version one – period two and checklist version two – period three.

The method was adapted and updated from research undertaken by Swinson et al.,[13] itself adapted from the original study by Offiah and Hall.[11] Data collection was undertaken by an experienced advanced radiographer practitioner and recorded on the data collection sheet, Figure 2.

A convenience sample was identified by searching the radiology information system (RIS) using the search term ‘skeletal survey’ using the date range 1st January 2007 to 30th November 2014.

Skeletal survey examinations undertaken for reasons other than suspected NAI and those requiring limited follow-up examinations were excluded. A total of 121 studies were analysed.

Images were viewed on Sectra® (Linköping, Sweden) IDS5 version 10.2.2 picture archiving and communication system (PACS) with Barco® (Kortrijk, Belgium) Nio E3620 3MP (2048 x 1536) dual monitors. The image viewing conditions were audited regularly for the purposes of maintaining suitable viewing conditions for medical image interpretation. Small batches were read at a time to ensure reader fatigue did not occur.

Skeletal survey examinations were assessed for content, quality and additional projections against the RCR / RCPCH standards.[10] For the purpose of this study the guidelines were assumed to require 20 standard projections as listed in Figure 2.

Figure 1

Figure 1. Skeletal survey checklist version 2.

Figure 2

Figure 2. Data collection sheet adapted from Swinson et al.[13]

The content of each survey was assessed for completeness against 20 expected standard projections and given a score out of a possible 20. The category 'exposures' was recorded separately to the category projections 'present' to reflect combined anatomy, for example the whole arm or leg included in one projection. The number of exposures was also scored out of 20. A projection of the whole arm (humerus, radius and ulna) in one would score two in the 'projections' category, but one in the 'exposures' category. Thus the difference between projection and exposure scores for a whole skeletal survey examination would reflect the combining of anatomy. Therefore, the bigger the difference between the 'projections' score and the 'exposures' score the more combined projections were taken. The higher the combined anatomy score, the lower the examination quality.

Table 1. Quality - quality score for each projection.

Table 1

Each projection was given a score for quality out of a possible seven, following the criteria laid out in Table 1 and recorded in the quality section of Figure 2. Each projection was given a single score for adequate positioning and exposure. If the anatomy of the body part was not included or was obscured due to rotation or collimation a zero score was recorded in the 'positioning' category. If all or part of the un-manipulated image was not visible a score of zero was recorded in the 'exposure quality' category. A possible score of two was available for appropriate use of markers, two for a metal marker applied at the time of the exposure and in the primary beam, one for an electronic marker applied after the image and none for an incorrect or absent marker. An anatomical marker included at the time of the exposure, rather than during post-processing, is considered best practice.[18] A score of one each was available for the presence of the radiographers' initials on the image and for the absence of artefact obscuring bony detail. A zero score was recorded in the 'artefact' category if any part of the hands of the person assisting with positioning appeared anywhere on the image in recognition of them receiving primary radiation exposure. The final score of one was available for the 'exposure index' falling within the manufacturers recommended range. 'Exposure index' is used by digital imaging equipment manufacturers to provide an estimated numerical value to the radiation exposure received by the image receptor.[19] This value can be used by the radiographer as a measure of appropriate image quality, the exposure index falling outside the recommended range suggests over or under exposure. Multiplying the scores for completeness by the scores for image quality generates a total quality score for the entire skeletal survey of 140.

Kolmogorov-Smirnov and Shapiro-Wilk tests for data normality were applied to the data in order to identify the most appropriate statistical analysis. Mann Whitney *u* tests and Independent *t* tests were undertaken using IBM SPSS Statistics version 22.

Consideration was given to ethical principles for conducting this study. Local NHS Trust Research and Development Department, clinical director, line manager and education provider approval were all obtained. No patient identifiable data was collected or stored as part of the data collection. The only data collected were those detailed above. NHS data storage and information governance regulations were followed throughout.

Results

A total of 121 skeletal survey examinations were analysed, in which 2107 standard projections and 64 additional projections were undertaken. All three quality criteria; completeness, combined anatomy and examination quality showed an increase between each period of investigation – no checklist (period one), checklist version one (period two) and checklist version two (period three). Kolmogorov-Smirnov and Shapiro-Wilk tests for data normality showed a mixture of normal and non-normal data.

The content of each examination, against the recommended 20 standard projections, showed a median of 13 for period one, 19 for period two and 20 for period three. In period one only 11% of examinations included the recommended 20 standard projections, this had risen to 39% in period two and 73% in period three. The range for period one was 7-20, for period two 8-20 and for period three 16-20. The content data is summarised in Table 2 and demonstrated graphically in Figure 3.

Table 2. Summary of skeletal survey quality scores.

Table 2

Table 3. Summary of skeletal survey quality indicators for each period. IQR – Inter Quartile Range, SD – Standard Deviation.

Table 3

Figure 3

Figure 3. Number of projections included in each skeletal survey for each period.

For the combined anatomy score, the higher the score the more combined anatomy in that examination. In this study the combined anatomical mean score reduced from 3.11 in period one, to 2.75 in period two, to 1.10 in period three representing a consistent improvement. The combined anatomical scores are summarised in Table 3 and shown graphically in Figure 4. The combining of anatomy, mostly the upper with the lower arms and legs, rather than omission of anatomy reduced the examination content scores in this study.

Each of the 2107 projections were assessed for quality out of a possible score of seven, multiplied by the 20 standard projections, which could therefore achieve a maximum score of 140 for each examination. The summary data are displayed in Table 2. In three cases the exposure index was not recorded. Rather than disregard these scores, the quality scores were converted to a percentage for each study. The quality data are summarised in Table 3 and shown graphically in Figure 5. The median quality scores for each period increased from 44% in period one, to 75% in period two and 83% in period three. The highest scoring quality criterion was exposure quality; the lowest two scoring criteria were absence of the radiographers' initials on the image and the presence of artefacts. Different quality scoring criteria were used in the previous studies[11,13] and therefore it was impossible to draw any meaningful comparisons numerically. The mean skeletal survey quality scores for each area assessed are shown in Table 4. The area of greatest improvement was observed in the increase of radiographer's initials on the images, increasing from a mean score of 3.52 in period one, to 11.86 in period two and 16.76 in period three. The area that showed the least improvement was the inclusion of artefacts. This showed only slight improvement from a mean score of 7.3 in period one, to 12.26 in period two and 13.97 in period three. The use of anatomical side markers also only showed a slight improvement from a mean of 21.26 in period one, to 30.88 in period two and 33.24 in period three.

Figure 4

Figure 4. Combined anatomical score in each skeletal survey for each period.

Figure 5

Figure 5. Quality percentage score in each skeletal survey for each period.

Table 4. Breakdown of mean skeletal survey quality scores for each period.

Table 4

Mann Whitney *u* Tests and Independent *t* Tests were applied to the different sections of the data. The Mann Whitney *u* Test showed a significant difference between period one and period two (U=51.5, n_1= 27, n_2=64, P<0.001) and between period two and period three (U=588.5, n_1= 64, n_2=28, P<0.003) for the number of projections for each skeletal survey. Hence the increase in numbers of projections included between each period showed statistical significance. For the combined anatomical score the Independent *t* Test showed no significant difference (t=0.611, n_1= 27, n_2=64, p=0.543) between period one and period two, however, between periods two and three a significant difference was shown using Mann Whitney *u* Test (U=501, n_1= 64, n_2=28, p<0.001). Throughout the study, statistical significance was achieved for the decrease in combined anatomical score, fewer examinations had arm and leg projections combined in line with the recommendations.[10] For skeletal survey examination quality a significant difference was shown between period one and period two (t= -8.154, n_1= 27, n_2=64, p<0.001) and between period two and period three (t= -4.143, n_1= 64, n_2=28, p<0.001) using Independent t Tests for both. Therefore statistical significance was also achieved for the increase in quality scores between each period and throughout the whole study.

Discussion

Overall there was a noticeable improvement in both content and quality scores of the skeletal survey examinations throughout the study period, with all quality measures showing a level of improvement. The introduction and modification of the checklists used by practitioners during the test, similar to those used successfully in other medical fields, have led to an improvement in skeletal survey quality. While the improvements observed have coincided with the introduction of the RCR / RCPCH standards,[10] the use of checklists are not specifically mentioned in the standards document. The results of this study support the successful practical application of the RCR / RCPCH standards using an imaging checklist format at a single multi-site organisation.

With regards to skeletal survey examination content there was a noticeable increase in the recommended projections. There was a further increase in this study in the inclusion of oblique chest radiographs of the ribs of 74% compared to 67% observed by Swinson et al.[13] A total of 64 additional projections were undertaken, representing an average of 0.61 per examination. There was an additional increase in the number of studies with all 20 recommended projections between the previous study 15%[13] and 41% in this study.

There was also a consistent increase in the skeletal survey examination quality scores throughout. It was possible to score a maximum of 20 for the recommended projections but still have anatomy combined in one projection, for example the upper and lower leg. Encouragingly both the combined anatomical scores and the quality percentage score showed sustained and corresponding improvement throughout the study. All individual scores that made up the quality percentage scores also showed improvement. The area of greatest improvement was observed in the increase the radiographer's initials on the images. Given its inclusion in bold print in both versions of the checklists and the improvement observed in this area specifically, supports the value of imaging checklists in skeletal survey quality.

The area that showed the least improvement and remains a concern was the inclusion of artefacts in the image. The highest number of artefacts represented those in which the anatomy of the person assisting with positioning was present in the image, rather than artefacts directly obscuring bony detail. This particular factor is, perhaps, less of a reflection of the successful application of the checklists and more of a reflection on other practical aspects.

Despite consistent improvement throughout the study the use of anatomical side markers applied at the time of image was also a concern. There were some studies that had no markers applied at the time of the exposure, perhaps supporting a reduction in skill and engagement in this area reflected in other research.[20] This factor is also, perhaps, less of a reflection on the success of checklists and more of wider factors discussed by Titley and Cosson.[21]

In a high proportion of cases the child presented with a specific injury that had a high association with NAI, such as a femoral fracture in a pre-walker. This often led to the child protection procedures being activated and a skeletal survey undertaken. The RCR / RCPCH standards make reference to the steps required when gallows traction has been applied and skull radiographs when CT of the brain has been completed.[10] In an attempt to understand why some skeletal survey examinations were incomplete it became evident during the data collection that omission of some areas included in recent imaging had taken place. The reasons for this were unclear, although this may have been an attempt to reduce the radiation dose. The standards make no mention of this eventuality and this study highlights the need for clarity in this area.

A number of limitations have been identified and should be considered in interpreting the results of this study. The use of a single observer and therefore lack of blinding reduces the study reliability; however the completeness scores are less susceptible as the number of examinations within a skeletal survey was recorded against the expected number. However, the use of multiple quality assessment methods and parity between them suggests these were not significant factors. The use of a single institution reduces external validity, although it is estimated that implementation of the RCR / RCPCH guidelines might have impacted other centres at different times making a direct comparative retrospective study challenging.

There were a number of other aspects not analysed in this study, but are likely to play an important role in the quality of skeletal survey examinations that might guide further work. These include; the role, background, qualifications, skills and experience of those present during the procedure, the value of more formal links, discussion and input between professional groups and the nature and quality of the engagement with child's parents or guardians.

Conclusion

Attaining high quality skeletal survey examinations for NAI has challenged UK and European providers. A body of evidence supports the value of safety checklists in a variety of complex health settings worldwide. This study has shown promising improvements to skeletal survey quality using imaging checklists in a single two-site NHS provider.

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Figure 1

Non-Accidental Injury Skeletal Survey Checklist

ID Label No: 3	Examination Label Date and Time

Date……………………………………

Radiographer 1 Name ……………………………Signed……………………………………

Radiographer 2 Name ……………………………Signed……………………………………

Named of witnessing staff member ……………………………………………………………

Parent/Guardian/ Foster parent name…………………………………………………………

Name of checking consultant radiologist	
Request card scanned to PACS	
Consent form scanned to PACS	

1. Skull views should be performed even if a CT head has been performed.
2. Chest should include the clavicles.
3. Limbs should be imaged in 3 separate images and exposures (e.g. upper leg, lower leg and feet.)
4. Only use metal markers. Initials of both radiographers on each image.

BODY PART	Dose	kVp/mAs
Skull AP		
Skull lat		
Skull Townes if needed		
AP chest (incl. clavicles)		
Rt oblique ribs		
Lt Oblique ribs		
Abdomen (incl. hips and pelvis)		
Lat cervical		
Lat thoracic		
Lat lumbar		

BODY PART	Dose	kVp/mAs
Rt arm humerus		
forearm		
DP hands		
Rt leg femur		
Tib/fib		
DP feet		
Lt arm humerus		
forearm		
DP hands		
Lt leg femur		
Tib/fib		
DP feet		

Reason for deviation from protocol including additional views acquired (if applicable) :

Figure 1. Skeletal survey checklist version 2.

Figure 2

Attendance Number	Completeness				Quality					
Image Number	Projection	Present (0/1)	Exposures (0/1)	Additional Projections (0/1)	Positioning (0/1)	Exposure Quality (0/1)	Marker (0/1/2)	Radiographer (0/1)	Absence of artefact (0/1)	Exposure Index (0/1)
1.	AP Skull									
2.	LAT Skull									
3.	AP Chest									
4.	LT Oblique Chest									
5.	RT Oblique Chest									
6.	Abdomen including pelvis and hips									
7.	LAT Cervical spine									
8.	LAT Thoraco-Lumbar spine									
9.	LT Upper arm									
10.	RT Upper arm									
11.	LT Forearm									
12.	RT Forearm									
13.	LT Femur									
14.	RT Femur									
15.	LT Lower leg									
16.	RT Lower leg									
17.	LT DP Hand									
18.	RT DP Hand									
19.	LT DP Foot									
20.	RT DP Foot									
21.										
22.										
23.										
24.										
25.										
26.										
27.										
28.										
29.										
30.										
Total										
Grand Total										

Figure 2. Data collection sheet adapted from Swinson et al.[13]

Figure 3

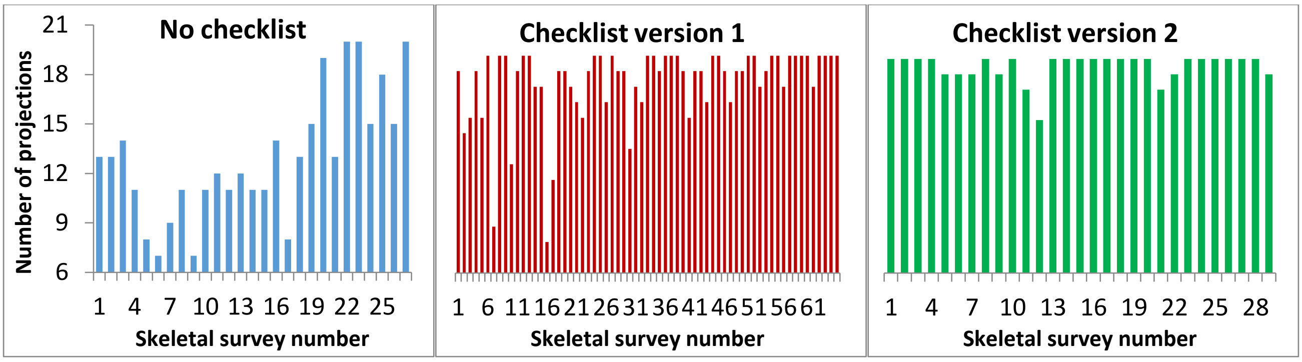

Figure 3. Number of projections included in each skeletal survey for each period.

Figure 4

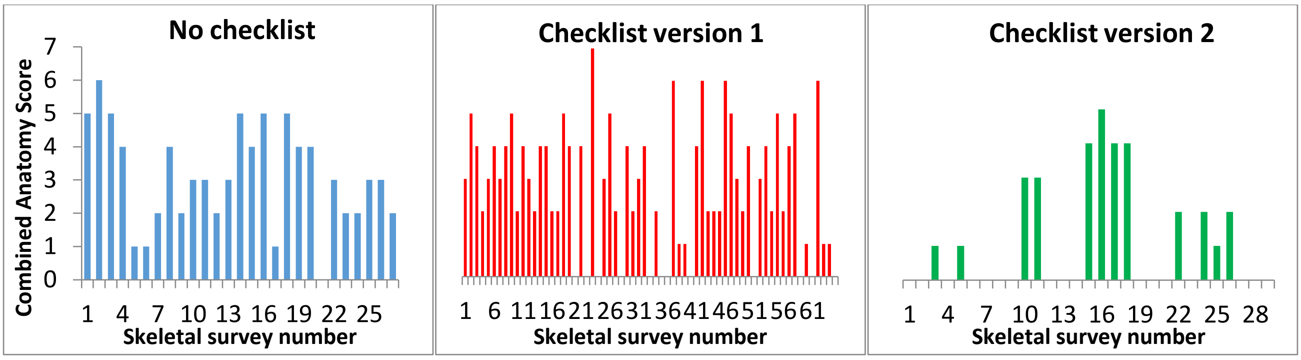

Figure 4. Combined anatomical score in each skeletal survey for each period.

Figure 5

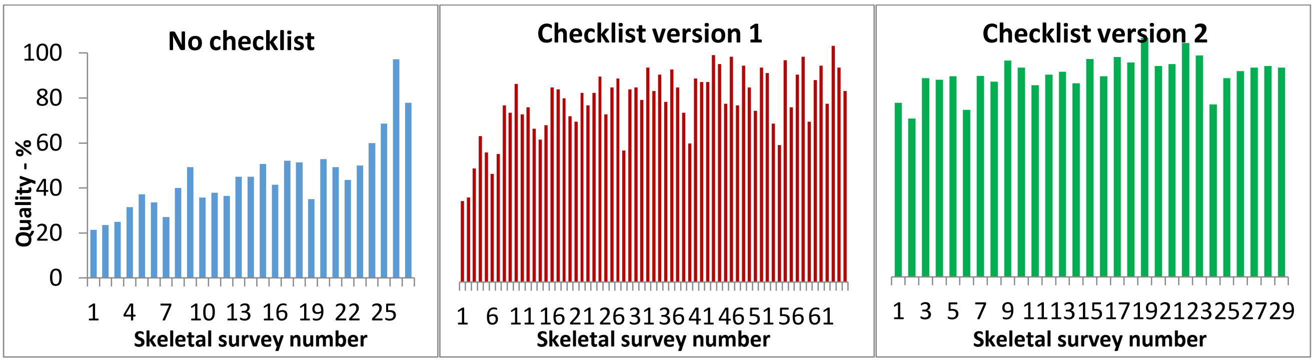

Figure 5. Quality percentage score in each skeletal survey for each period.

Table 1

Number	Factor	Score
1.	Positioning	1
2.	Exposure quality	1
3.	Marker	2
4.	Radiographer initials	1
5.	Absence of artefact	1
6.	Exposure index	1
Image total		7
Total	(7x20 projections)	140

Table 1. Quality - quality score for each projection.

Table 2

	Quality Indicator	
Time period		Median quality score (max. 140)
		Median
	Period one – no checklist	61
	Period two – checklist one	105
	Period three – checklist two	114

Table 2. Summary of skeletal survey quality scores.

Table 3

Time period		Quality Indicator					
		Content Projections		Combined anatomical score		Examination quality Percentage	
		Median	IQR	Mean	SD	Median	IQR
	Period one – no checklist	13	4	3.11	1.53	44	16
	Period two – checklist one	19	2	2.75	1.9	75	15
	Period three – checklist two	20	1	1.1	1.59	83	6

Table 3. Summary of skeletal survey quality indicators for each period. IQR – Inter Quartile Range, SD – Standard Deviation.

Table 4

Table 4. Breakdown of mean skeletal survey quality scores for each period.

	Positioning	Exposure	Side Markers	Initials	Artefacts	Exposure Index
Period One	8.56	13.00	21.26	3.52	7.30	9.56
Period Two	14.62	18.12	30.88	11.86	12.26	12.32
Period Three	16.97	19.69	33.24	16.76	13.97	14.62