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Abstract

Background: Nurse practitioners (NP) are an integral part of the urgent and emergency care workforce in the United Kingdom providing safe and effective care. Despite this, there is limited research assessing the ability of NPs to correctly interpret isolated paediatric limb injury radiographs in the urgent and emergency care environment.
Objective: The aim of this study was to compare the accuracy in interpreting isolated paediatric limb radiographs between NPs and consultant radiologists.
Setting: A nurse-led urgent care centre (UCC) in central London, United Kingdom.
Participants: 296 paediatric patients with isolated limb injuries who had a radiograph requested and interpreted by an NP.
Methods: Thirteen NPs (adult registered) with various backgrounds and qualifications participated in this prospective, single-centre healthcare analysis. Review of all clinical presentations at the UCC over a 3 - month period (September to November 2017) identified 296 paediatric patients (aged 2-15) who received a peripheral limb radiograph. Clinical records for each patient were analysed to document demographics, mechanism of injury, NP examination findings, radiographic interpretation and formal radiologist report. NP interpretation of each radiograph was classified as definite fracture, possible fracture or no fracture. This was compared to the final radiologist report (considered the gold standard) to calculate the sensitivity and specificity of NP radiograph interpretation.
Results: NPs reported a total of 94 radiographs (32%) as definite fracture, 176 (59%) as no fracture and 26 (9%) as possible fracture, as compared to radiologists at 71 (24%), 218 (74%) and 7 (2%). A total of 242 (82%) of radiographs were correctly identified by NPs, while 54 (18%) were incorrectly interpreted. The sensitivity of the NP limb radiographic interpretation was 92%, with a specificity of 78%.
Conclusions: The findings validate the clinical and diagnostic skills of NPs in the interpretation of isolated paediatric limb radiographs.

Keywords:

X-ray, nurse practitioner, emergency care, advanced practice, urgent care centre, paediatric

Introduction

Nurse practitioners (NP) are an essential part of the National Health Service (NHS) workforce in the UK. In 2016/2017, 23 million patients attended emergency departments (ED) across the UK and with this ever-increasing demand on urgent and emergency care (UEC) services, NHS England plans to support new advanced clinical practice nurse roles to make a demonstrable impact to UEC (NHS England 2017). Moreover, due to this rising demand for unscheduled care, more NPs are expected to expand their scope of practice to both the adult and the paediatric population.

The NP role was developed in the UK during the 1980s as a result of increased junior doctors working hours, shortage of doctors and increased patient waiting times (Bagley 2018). Initially, these NPs comprised of senior experienced emergency nurses, who received brief formal training and were usually restricted to the care of the adult population. Their main role was to treat a wide range of minor wounds and injuries that were protocol driven, but more importantly they were authorised to request and interpret radiographs. The level of radiographic training was variable and usually involved in-house training by ED consultants and consultant radiologists (Meek *et al*. 1998). However, they were bound by set radiographic guidelines and protocols that usually prohibited radiographic requesting for paediatric patients. As the NP role expanded over the last three decades to meet the rising demand on UEC services, so has their scope of practice, skills and knowledge base, which now regularly involves caring for the paediatric population.

Literature Review

A literature review was undertaken examining NPs ability to accurately interpret radiographic images in the paediatric population. The Cochrane library database (March 2018) was searched for any existing reviews that involved radiographic interpretation within an emergency department setting with no results. Medline (1946 – March 2018), Embase (1974 – week 13, 2018) and CINAHL (1981 – March 2018) were accessed. A facet analysis was used to extrapolate and to identify all relevant research studies relating to the search topic. The search strategy consisted of the following main facets – Nurse practitioner, children, radiography and interpretation. Synonyms were queried for the all the main facets. Truncation searches for Medline and Embase were used as a $ and as an * in CINAHL (praction$ or praction*) to the appropriate facets. The use of a wildcard as ? in Medline and Embase and as a # (p?diatric or p#diatric) increased the sensitivity of the search. Headings were exploded to include all the search terms. The use of the Boolean operator 'OR' was used once each facet had been searched to combine all the synonyms. On completion of all facets, the Boolean operator 'AND' was applied to combine all subject search terms. All results were limited to English language and in humans only. No restrictions were placed on study designs, publication date or country of origin. Exclusions applied if any study did not include NPs in the study design and adults were initially excluded from the search strategy, but no studies were identified in any database when using children or its synonyms as a main facet search. A further database search was undertaken with the omission of children and its synonyms.

From this review of the literature, 12 studies were identified that examined the nurse practitioner role focusing on radiographic interpretation and accuracy using different methodologies (Overton-Brown & Anthony 1998; Meek *et al.* 1998; Freij *et al.* 1996; Sakr *et al.* 1999; Tachakra 2002; Benger 2002; Barr *et al.* 2000; Summers 2005; Coleman & Piper 2009; Swaby-Larsen 2009; Lee *et al*. 2014; Snaith & Hardy 2014). Overall these studies demonstrated that NPs can achieve a high level of accuracy in radiographic interpretation with a satisfactory level of sensitivity and specificity (**Table 1**). Tachakra (2002), reported a high level of accuracy with a sensitivity at 95.66% and specificity at 98.75% while Snaith & Hardy (2014) reported 100% sensitivity and specificity in radiographic accuracy interpreted by the NPs in the immediate reporting arm compared to the delayed reporting group (not at the time of patient attendance) which achieved 91.8% sensitivity and 98.8% specificity. They concluded that the NPs radiographic interpretation is comparable to the medical clinicians. Lee *et al.* (2014) aimed to benchmark NPs against ED consultants in their ability to correctly interpret adult limb radiographs. Sensitivity for the NPs was 91% compared to the ED consultants at 88%. NP specificity was 85% compared to the ED consultants at 91%. The study validated the interpretative ability of isolated limb radiographs by NPs compared against ED consultants. However, they found that NPs recorded an increased number of 'possible fractures' compared to the ED consultants, a possible explanation for this is the length of the ED clinicians experience compared to the NPs.

Insert Table 1 here

A major limitation of the studies identified in the literature was that only seven of the 12 studies included children of varying ages in their results (Freij *et al.* 1996; Benger 2002; Tachakra 2002; Meek *et al.* 1998; Coleman & Piper 2009; Swaby-Larsen 2009; Snaith & Hardy 2014). The study by Snaith & Hardy (2014) involved the largest number of children ranging from age 0-17 years (n=226), who had a radiograph interpreted by either a NP or medical practitioner, two false negatives and seven false positives were recorded. However, it is unclear which clinical group reported these interpretative errors and exactly how many children were seen by a NP. Overall, there was a marked variation in the number of radiographic images used in all studies, ranging from 20 to 2000 images. Moreover, the paediatric sample size across studies is small, if at all present.

Numerous limitations of the studies include mixed methodologies and heterogenous data collection methodologies. These included test bank images, rating scales, audits, comparisons against varied seniority of medical colleagues and comparisons against consultant radiologist or radiographers. As highlighted, Lee *et al*., (2009) state that there was a lack of homogeneity within interpretation of the findings and data analysis consisted of sensitivity and specificity levels, confidence intervals and Kappa statistics. Thus, the aim of this study was to compare the accuracy in interpreting isolated paediatric limb radiographs between NPs and consultant radiologists in a nurse-led urgent care centre (UCC).

Methods

Study setting and population

At the time of the study, the author (AA) worked in an inner London UCC that treats and diagnoses both adult and paediatric patients with a wide range of illness and injuries. The unit is staffed by 13 NPs working on a rotating shift work pattern and is staffed by one General Practitioner (GP) during opening hours. The role of the GP is to treat medical issues only, whereas the NPs treat both injuries and illness' in adults and children from age 2 and above (policy excluded care of children under the age of 2 years). Annual attendance is approximately 26,000 patients per year, nearly 50% of these patients are children and it is equipped with onsite X-ray facilities. In 2017, 9,643 children attended the UCC, from which 2883 children were treated for injuries. The service runs from 8am to 9pm seven days a week and has the benefit of an onsite radiography unit which is staffed and managed by a large local tertiary healthcare trust. A service agreement policy is in place between the two trusts regarding the radiography unit, as the UCC Trust does not manage any radiology services within the trust. This local tertiary healthcare trust provides the formal reporting on all radiography that has been undertaken at the UCC by their team of consultant radiologists. For this reason, children are classified as those under 16 years, as patients above 16 years are cared for by adult medical specialists by the local tertiary healthcare trust. They provide the UCC with access to a radiologist for immediate reporting if the NPs or GPs require this during opening hours.

Ethics

Ethical approval for the service evaluation was granted by the Healthcare Trust from the Clinical effectiveness team. All data were stored electronically on an excel file using a password protected computer. All patient information was de-identified for privacy and confidentially purposes according to general data protection regulations 2018 (GDPR, 2018).

Study design

The study was conducted at the UCC in January 2018. Three months of data was retrospectively collected from 1st September 2017 to 30th November 2017 from all children aged between 2 – 15 years who presented to the UCC with a traumatic limb injury and subsequently received an X-ray.

Data sources

At the UCC the SystmOne™ electronic health record was accessed using the audit function within the programme to generate a report for the study period. This system was also the source of all demographics, triage information, practitioner notes, diagnostic requests and radiography results including radiologist formal report. To identify all patients required for the study, the following filters were applied: children aged between 2-15 years, 1st September 2017 - 30th November 2017 and radiography requested. Once the report was generated a manual search was conducted on every patient record that was generated by the report and all corresponding data that was collected was entered into an Excel spreadsheet. The UCC operates a filmless radiology environment. All formal reports by the consultant radiologist are reported using the picture archive and communication system (PACS). As this system is linked to SystmOne™, a list of formal X-ray reports would usually appear on SystmOne™ that required manual authorisation from the staff to ensure there were no missed fractures for quality control purposes. Occasionally, there would be communication errors between the two systems and a formal report would not be visible on SystmOne™, despite a request for radiography being logged and visible on SystmOne™. This would be resolved via a manual check of the patient on PACS to obtain the formal report to collect the required information which was then added to the excel spreadsheet for analysis.

Data collection

Every child's health record that was generated through the search was manually checked and included in the final data collection. No exclusion criteria were imposed as the NPs at the UCC can only request X-rays for extremity traumatic injuries only. Extremity trauma features radiology of the arm distal to and inclusive of the shoulder and elbow and radiographs of the leg, distal to and inclusive of the lower femur and the knee. Exclusions include paediatric hip X-rays, as NPs are unable to request these at the UCC. NPs notes were scanned for the required data. Data were collected using an excel spreadsheet with column titles comprising: date of arrival, age, gender, mechanism of injury (sport, fall, blunt trauma or other). Further data were collected if any of the following signs and symptoms were present: swelling, bruising, deformity, point bony tenderness, ability to weight bear (immediately and in the UCC) and whether the injury occurred at school. If the required data were present in the notes, a 'Yes' was entered in the matching data column, or if symptom findings were documented as absent, a 'No' was entered. If symptom findings were not documented in the NPs clinical notes, this was left blank under the corresponding data column. The specific anatomical location of the requested X-ray was also documented – for example, 'Ankle Left' and 'Wrist Right'.

The consultant radiologist's formal X-ray report was viewed as the gold standard for presence or absence of a fracture, which was crosschecked against the NPs interpretation. The NPs and radiologist's radiographic interpretation was entered as 'Yes' (fracture present), 'No' (no fracture) or 'Possible' (potential fracture). If a 'Yes' or a 'Possible' was reported by either professional, a brief description of the fracture or other abnormality was documented if available. McRae (2006) defines a fracture as a loss of continuity or disruption in the substance of the bone and this covers all terms of disruptions ranging from hairline fractures to multi-fragmentary fractures.

Sensitivity and specificity

In the presence of a fracture, the term positive would be used, if absent, the term negative would apply. To allow for the analysis of sensitivity and specificity, only four possible outcomes apply.

- True positive (TP): radiograph has detected the patient to have a fracture and was reported by both the radiologist and NP.
- True negative (TN): radiograph has detected the patient to have no fracture and was reported by both the radiologist and NP.
- False positive (FP): radiograph does not show a fracture as reported by the radiologist but the NP has determined a fracture is present.
- False negative (FN): radiograph does show a fracture as reported by the radiologist but the NP has determined that no fracture is present.

Altman & Bland (1994) state that sensitivity and specificity can quantify the diagnostic accuracy of a test. Sensitivity is defined as the proportion of true positives that are correctly identified using the test and specificity is the proportion of true negatives that is correctly identified by the test. Sensitivity is calculated as TP + FN/TP and specificity is calculated as TN + FP/TN. In order to calculate sensitivity and specificity, all radiographs that were reported as 'Possible' by the NPs were included in the calculation as a positive result. Lee *et al*.(2014) also categorised 'Possible' fractures as a positive for the purpose of their analysis of sensitivity and specificity; results for sensitivity and specificity were comparable when 'Possible' fractures were categorised as negative.

Results

A total of 296 adolescents and children presented to the UCC between 1st September and 30th November 2017 with an isolated limb injury that required a radiograph. Greater numbers of males presented than females and upper limb injuries occurred more frequently than lower limb injuries (**Table 2**).

Insert Table 2 here

In terms of upper limb X-ray requesting (n=187), NPs requested finger X-rays in 35% of upper limbs X-rays followed by 25% of the wrist, 13% of the hand and 12% of the thumb. Lower limb X-ray requesting (n=109) by the NPs showed 41% were of the foot, 37% of the ankle and 11% of the knee. Signs and symptoms were also recorded, with point bony tenderness and swelling identified predominantly in upper limb injuries (**Figure 1**).

Insert Figure 1 here

The consultant radiologist interpreted 71 (24%) radiographs as definite fractures, 218 (74%) as no fracture and seven (2%) as possible fractures. This compared with NPs who interpreted 94 (32%)radiographs as definite fractures, 176 (59%) as no fracture and 26 (9%) as possible fractures (**Table 3**). In one case, a NP reported a definite fracture, yet the radiologist reported it as a possible fracture. Overall, a total of 242 (82%) radiographs were correctly identified by NPs, while 54 (18%) were incorrectly interpreted. Taken together, the NPs achieved a sensitivity of 92% (95% CI: 84-97%) and a specificity of 78% (95% CI: 72-83%) against the gold standard of radiologist interpretation (**Table 4**).

Insert Table 3 here

Table 4 demonstrates the raw data of all clinical groups interpretation in order to calculate the sensitivity and specificity after changing all the 'Possible' interpretations to a positive finding. The calculated sensitivity, specificity, positive and negative predictive values as demonstrated by the NPs in **Table 5**.

Insert Tables 4 and 5 here

The six missed radiographic abnormalities that were incorrectly interpreted by the NPs were mostly left upper limb and had all been interpreted as negative by the NPs - these were: fracture to first metacarpal of left thumb, left little finger fracture proximal phalanx, left torus fracture distal radius and one right hand with pisiform fracture. The two lower limb fractures which were interpreted as negative were: left buckle fracture to distal fibula and Salter Harris 2 fracture of the medial femoral condyle of the left knee.

Discussion

In this prospective study of 296 adolescents and children, the level of agreement in interpretation of paediatric limb radiographs by NPs was examined. When compared against the gold standard of a consultant radiologist, the accuracy of the radiographic interpretation of paediatric radiographs by the NPs demonstrated a sensitivity of 92% and a specificity of 78%. Overall, these results compare favourably to prior studies which documented sensitivity levels ranging from 90% to 96% (Benger 2002; Freij *et al*. 1996; Lee *et al*. 2014; Snaith & Hardy 2014; Tachakra 2002). However, only four of these studies involved children (Benger 2002; Freij *et al*. 1996; Snaith & Hardy 2014; Tachakra 2002).

Further analysis of the results revealed the NPs interpreted 26 (9%) radiographs as a 'Possible fracture' in comparison to the consultant radiologist who reported seven (2%) potential fractures. Interestingly, in one case the NP diagnosed a middle finger fracture, whereas the consultant radiologist reported it as a 'Possible fracture'. These equivocal results appear comparable to previously reported studies (Benger 2002; Swaby-Larsen 2009; Lee *et al*. 2014). Paediatric radiographs can be challenging to interpret due to the presence of growth plates in skeletally immature children, which could lead NPs to misidentify them as fractures on an otherwise normal radiograph – it is conceivable that this contributed to the high number of false positive results (McRae, 2006). Thomas *et al*. (1992)

reported that finger radiographs – particularly in children – had the highest rate of misinterpretations, closely followed by the ankle, wrist, foot, elbow and hand. Moreover, Deakin *et al*. (2015) agree that diagnostic errors occur the highest in the extremities, with feet being the first, followed by knee, elbow, hand, wrist, hip and ankle. Critically, Benger (2002), suggested that it is preferable for NPs to report false positives than negatives, thereby minimising harm to patients and Maebrook & Dale (1998) report that overreading radiographs was a consistent finding in their evaluation of a nurse-led minor injury unit.

Implications for practice and recommendations

Irrespective of the false positive finding, the NPs still achieved a high level of sensitivity and satisfactory specificity without any formal X-ray interpretation training and with little prior paediatric experience. None of the nurses at the UCC are Registered Children's Nurses and very few had extensive prior paediatric nursing experience, as majority of NPs had come from an adult ED background. As part of the Trust protocol for non-medical referrers for radiology examinations, the NPs must undertake an ionising radiation medical exposure regulation course and attend a 'Red Dot' study day. 'Red Dot' is aimed at doctors and NPs who work in UEC and is a one-day course that provides a structured approach to interpreting radiographs requested in the ED. This teaching programme is based on a series of short lectures, interactive tutorials and teaching quizzes, yet the course content includes very little paediatric radiology. This suggests that the NPs are interpreting the radiographs based on clinical experience alone. Furthermore, it would assume that with increased experience, a higher level of accuracy would be achieved, as reported by Overton-Brown & Anthony (1998). Moreover, most published studies discuss the lack of formal training for NPs in radiographic interpretation. Further implications to practice should include clinical feedback by monitoring false positives and false negative results and providing feedback to individual NPs. Furthermore, areas identified for improvement include reducing NPs false positive results. This suggests that formal structured paediatric teaching sessions should be conducted for NPs with a focus on the normal appearance of growth plates of the skeletal structure specific to paediatric limb radiographs. The Royal College of Paediatrics and Child Health (2018) have developed standards for Children in Emergency Care settings and this can be incorporated into local education.

Future recommendations for practice proposed include improving accessibility to specific educational courses for registered general nurses and NPs who work in an UEC environment, to equip them with the skills to meet the specific needs of children. From a NP point of view, further recommendations proposed would include the development and accessibility of accredited training courses for NPs aimed specifically in the treatment of common paediatric emergency presentations, such as, minor illness, injuries and interpretation of paediatric radiographs. At present, there is a paucity of courses covering these topics. The ideal would be specially trained NPs with paediatric skills. This does not signify that these specially trained NPs can replace paediatric NPs or children's nurses, as always, the gold standard of care for children should be qualified children's nurses or paediatric NPs. Moreover, it will equip the registered general nurses with the appropriate skills set and confidence needed in looking after children and adolescents until we can increase the numbers of paediatric NPs.

Limitations

One limitation of the analysis is that it was a single-centre study and did not include a review of the appropriateness of radiographic requests by the NPs. Overall, 74% of all radiographs were deemed normal by the consultant radiographer. When reviewing the clinical notes, there were numerous cases where the clinical evidence supporting a radiograph examination was not documented, thereby raising questions about the validity of the request. It is paramount that unnecessary exposure to radiation is reduced by avoiding unnecessary radiographs, especially in the paediatric population. In particular, increasing competency in NPs with appropriate education and training, should minimise false positives by reducing overreporting and misinterpretation of paediatric radiographs. As this is a single site healthcare analysis, the radiographic interpretation abilities of the NPs in this study may not be representative of other NPs working within the United Kingdom. Therefore, further research in this area is recommended.

Conclusion

This research addresses a significant gap in the research literature, by validating the ability of NPs to accurately interpret paediatric limb radiographs. As a result of the increasing demand on UEC services, the NPs scope of practice has expanded to involve the care of paediatric patients. In order to keep up with this rising demand, additional paediatric specific education and training in radiographic interpretation is strongly recommended, so that improvements in the sensitivity and specificity can be seen in future analysis of NPs' radiographic interpretation skills. The continued support and educational development for NPs will provide a safe and effective workforce caring for paediatric patients with isolated limb injuries.

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