Ultrasonography in the assessment of hand injuries in children: A systematic review

Echographie pour de l'évaluation traumatisme de la main chez les enfants: une revue systématique

INTRODUCTION

Hand injuries, which encompass fractures and soft tissue injuries,[1] is the most common form of injury in the paediatric population, and is a frequent cause for emergency trauma unit admission with an annual incidence in the under 16 age group in the United Kingdom estimated to be 418 per 100,000.[2,3]

Despite the common presentation of paediatric hand injuries, recommendations for investigations are limited due to paucity of published guidelines in the literature which has led to diagnostic mismatch and inappropriate management.[1,2] For example, a recent retrospective study from a tertiary trauma centre reported a higher diagnostic mismatch for hand injury in the paediatric population (11%) compared to the adult population (4.6%), with incorrectly diagnosed fractures (22.2%) and missed fractures (11.1%) being the most common reasons.[2]

Hand injuries are important to diagnose and treat promptly as per recommended guidelines by hand surgical societies. Undiagnosed fractures, tendon and ligament tears can lead to the inability to move the hand, stiffness, displacement, and joint instability, leading to considerable functional impairment.[4-6]

The current standard of diagnosis is through physical examination and X-ray, which can prove at times to be challenging as children can be difficult to examine.

Ultrasonography (US) is a portable, non-ionising imaging modality that allows rapid evaluation of anatomical structures in real-time.[7] Benefits of US include no requirement for sedation, the ability to assess anatomical structures dynamically, and its relative low cost. In the adult population, US has already been shown to improve accuracy in diagnosing hand pathology such as tendon injury, fractures, ligament injury, nerve injury, blood vessel injury, and foreign bodies.[8] However, few studies focus on the child population, with only one narrative review focusing on the application of US to diagnose hand injury in children.[7] This systematic review aims to evaluate US as a diagnostic tool in paediatric hand injuries, and to provide recommendations for its use.

METHODS

The databases accessed for the literature search were as follows: PubMed, Google Scholar, EMBASE, Scopus, Cochrane Database of Systematic Reviews and University Library of York, Keele, Edinburgh and King's College London. All databases were accessed from 26th May 2022 to database inception. The search strategy involved using a combination of MeSH terms (Supplemental Table S1) and a similar approach was used for keywords. Forwards and backwards citation searching as well as grey literature was used to identify relevant studies for inclusion into this study. This review was reported according to the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines,[9] and the study protocol was registered with PROSPERO (CRD42022316590).

The inclusion criteria consisted of 0-17 year old patients, hand as primary injury site, acute (immediate injury typically due to trauma) and chronic injury (injury due to repetitive use over time), human subjects and English language articles. Exclusion criteria included patients aged 18 years or above, patients with an undetermined follow-up duration, injured anatomical structures proximal to the carpal bones, congenital hand differences, bone disorders (eg., cancer, osteogenesis imperfecta, rickets), foreign bodies, and conference abstracts. Case studies and case reports were included in the inclusion criteria due to the relative rarity of ultrasonography use in children for diagnostic purposes in hand injury. All articles were downloaded, and any duplicates were deleted. The remaining articles were screened by two authors independently (L.T, C.S) and either included or excluded into this study using the criteria. Full text was retrieved and further analysed in the case of any discrepancies (L.T, C.S, Y.M, S.A-A), and was resolved through discussion from all authors until an agreement on the study's inclusion and exclusion was made.

In determination of methodological quality and risk of bias, full-text articles were assessed using the ROBINS-I tool for non-randomised studies of interventions (Supplemental Figure S1).[10]

Data extraction was completed by three authors (L.T, C.S, S.M). Analysis of data was completed conforming to Patient, Intervention, Comparison and Outcome (PICO). Data was extracted for the following categories: general information, patient's demographic, injury information and US information. General information included year of publication, study design, number of hands with trauma, and number of patients. Patient's demographics included age, sex, previous surgery, and comorbidities. Injury information included injury mechanism, resulting injury, digit injured, structure injured, reason for referral and whether injury was chronic or acute. US information included US involvement in diagnosis and US involvement in management.

For the purposes of the systematic review, the following terms were defined: ‘children’ as those from birth until their 18th birthday,[11] ‘hand’ as all physical structures including skin, tendons, nerves, blood vessels, bones, and joints present from the carpal bones and distally,[2] and ‘injury’ as a physical and or anatomical change caused by an external factor not due to a congenital hand difference, which can be induced by a variety of mechanisms such as penetrating injury and blunt trauma.[12] Both acute and chronic time courses were included based on how the author in each study reported. We defined acute conditions as having a short, severe course, usually reversible and less than 3 months and chronic conditions as permanent, non reversible and typically lasting more than 3 months. Diagnoses in the studies were considered to be the stage at which management was administered, and was compared to surgical or follow-up investigations or findings which confirmed or refuted the diagnosis. We looked into the number of diagnostic steps in each injury to see when ultrasound was used; a diagnostic step was defined as a single intervention used during the workup of an injury, for example, clinical examination, X-ray, US, CT scan, MRI scan would demonstrate five diagnostic steps.

RESULTS

The literature search yielded 21 studies from the initial 11,860 articles found in the databases (Figure 1). The following studies were found: 18 case reports, two case studies, one cross sectional study. The year of publication ranged from 1970 to 2022. There were no randomised controlled trials.

Thirty patients (30 hands) were included from the 21 studies where 22 patients were male, and eight patients were female. The age range of patients was 2-17 years, the median was 14.5 years, and the average age was 11.4 years. There were eight patients aged five and below and 22 patients over the age of five.

Injury

In 30 hands, injury affected six structures: tendon (n =12), blood vessel (n = 10), bone (n =4), ligament (n =3), and nerve (n =1). The following diagnoses were made: pseudoaneurysm, MCPJ ligament injury, fracture, tendon rupture, tendon tear (partial rupture), ulnar collateral ligament rupture, nerve tethering, arteriovenous fistula, tendon entrapment, and radial sesamoid distal displacement of the thumb MCPJ.

In the under-five age group, the majority of the diagnosis made were pseudoaneurysms (n =5) followed by tendon rupture which was found in two hands. In the over five age group, ligament injury was the most common diagnosis (n =5) followed by fracture (n =4), tendon rupture (n =4), and partial tendon tear (n =3). Pseudoaneurysm was diagnosed in two hands in this age group.

Blunt trauma accounted for the majority of the injury mechanisms (n =12) whereas injuries from sharp objects were found in 8 hands. A large proportion (n =10) of the injury mechanisms were not reported or unknown to parents. More specifically, in the under-five age group, the majority of hand injuries were caused by sharp objects. In the over five age group, blunt trauma was the most common injury mechanism (n =11).

The average time from injury to US use was 243.9 days, the median was 49.5 days, and range was 0-3650 days.

Ultrasonography use

The average number of diagnostic steps performed was 3, the median number of diagnostic steps was three, and the range was one to six diagnostic steps. The category needing the most diagnostic steps was blood vessel which required an average of three diagnostic steps and the range was 1-6. Twenty-six diagnoses were made by US, five diagnoses were made by diagnostic steps before US use, and two diagnoses were made by diagnostic steps after US use. An average of 2 diagnostic steps, a median of two diagnostic steps, and a range of one to five diagnostic steps were made before US (Table 1).

Ultrasonography diagnostic accuracy

US had the highest diagnostic accuracy of 100% in all ligament injuries (n =6), nerve injuries (n =1), and 90.9% in tendon injury (n =11). Although US was used to diagnose 25% of bone injuries, when a diagnosis was made using US, this matched the same findings as the previous diagnosing modality (X-ray) in all of the cases. US confirmed tethering of the nerve in one hand, leading to paraesthesia. US diagnosed 75% of sharp object injuries (n =6), and 91.7% of blunt trauma injuries (n =12).

US diagnosed 87.5% of pathologies in the under-five age group (n =7) and showed 100% congruence with the diagnosing modality (n =8). US diagnosed 81.8%

of pathologies in the over five age group (n =18) and showed 100% congruence with the diagnosing modality (n =22). US diagnosed 86.4% of males and 87.5% of females and showed 100% congruence with the diagnosing modality in both sexes (Table 2).

US diagnosed two pathologies that were not detected by previous imaging including: a scaphoid fracture missed on X-ray, and a radial sesamoid distal displacement of the thumb MCPJ missed by X-ray. US was unable to diagnose three pathologies: two pseudoaneurysms diagnosed by MRI and one by arteriogram.

Management

The use of ultrasonography led to a management plan in 83.3% of hands (n =25). Ultrasonography led to management in all ligament injuries (n =6), 90.1% of tendon injuries (n =11), and 70% of blood vessel injuries (n =7). Injuries where ultrasound did not guide management include: Jersey Finger type IV [23], Salter-Harris Type III fracture[28]. Surgical exploration confirmed ultrasonography findings in 83.3% (n =25) hands.

Surgical confirmation did not confirm ultrasonography findings in one hand which had a pseudoaneurysm of the radial artery caused by a foreign body.[19] One hand was lost to followup and did not attend their MRI or electromyogram study of the ulnar nerve after ultrasonography diagnosed nerve tethering.[30] One hand received a referral to orthopaedics for a high grade UCL tear.[30] Of note, surgical exploration was not performed in four hands.

Other imaging

Clinical examination was performed in most hands (n =29) and aided diagnosis (was part of the diagnostic steps leading to management) in 24 hands. Clinical examination did not take place in one hand and misdiagnosed two hands. X-ray was performed on most hands (n =18) but made few diagnoses (n =4), and aided diagnosis in four hands with a majority of confirmed diagnosis made by US. X-ray did not diagnose or aid diagnosis in seven hands with reasons including a normal radiograph (n =6) and mild soft tissue swelling, where a scaphoid fracture was missed. CT was performed in two hands but did not diagnose any hand injury. CT confirmed diagnoses made by US in one hand and MRI in one hand (follow up CT to find foreign body in a pseudoaneurysm). MRI was performed in one hand and diagnosed pathology in one hand. The results of our study are found in Table 3.

DISCUSSION

There is a lack of published guidelines and protocols for the assessment of paediatric hand injuries with a clear need to standardise investigations to improve paediatric patient outcomes. The only standardised guidance available mentioning investigations focuses on acute MSK infection, which states that no single investigation algorithm is completely reliable.[1] In this guidance, US is considered as an additional second line modality after blood tests, radiographs, and as an alternative to MRI if it is not available in these guidelines.[1]

Research suggests a higher diagnostic error in hand injuries within the paediatric population compared to the adult population, and thus the appropriate choice of investigative method in paediatric hand injuries remains pertinent in overall management.[2] Despite clear evidence in the benefit of US as a diagnostic tool for hand injury within the adult population, the use of this modality within the paediatric population has been largely not well described as an early diagnostic tool.[40]

Our results suggest that ultrasonography is an accurate early diagnostic tool for paediatric bone, tendon, ligament and nerve injury. Although US was not a popular diagnostic modality for bone injuries, in cases where X-ray was used as a diagnostic tool after clinical examination, US was used subsequently to localise the X-ray findings, and had a 100% concordance with the previous X-ray findings. One further case in our literature search highlights an advantage of US, where a subtle scaphoid fracture was initially missed by X-ray, but subsequently found on ultrasound imaging.[6]

Similar to our findings, other studies report a high accuracy in diagnosing tendon injury using US, with reports of sensitivity, specificity, and accuracy of 93.8%, 97.8% and 95.8% respectively when US was used to diagnose tenosynovitis and partial rupture of tendon.[32] For ligament injuries, US also demonstrated high precision in other studies with a sensitivity of 96% compared to clinical examination at 97%, and MRI at 99%, and a specificity of 91%, compared to 85% in clinical examination, and 100% in MRI.[33] Although these studies focused on US use in the adult population, the effectiveness of this imaging modality for identifying injury in these anatomical structures is important to note.

In our literature search, only one narrative literature review on the use of US for paediatric hand injuries was found.[7] This review described the use of ultrasonography and its findings for injuries involving flexor tendons, the pulley system, volar plates, collateral ligaments, and the extensor mechanisms. The authors also looked at juvenile idiopathic arthritis, lesions, and masses,[7] and concluded that US is a valuable tool for assessing injuries, inflammation and masses in the hand. Similar to the findings in our review, Crum et al. also noted that the dynamic imaging with ultrasonography allowed improved evaluation of ligament and tendon injury as well as helping to guide treatment decision-making for the pre- and postoperative patient.

Very few articles met the inclusion criteria as there is lack of research in this area. As a result, no randomised controlled trials were included in the present review. The majority of articles that met the inclusion criteria were case studies or reports, as the use of US in the investigation of hand injury in children is not the current clinical standard.[1] This unavoidable inclusion of case studies and reports has resulted in a higher degree of selection bias in the present review; however, this indicates that the use of US in paediatric hand injuries is a neglected area of research which would benefit from further scientific inquiry.

A significant bias in our study is that we only selected articles that focussed on US as an imaging modality and thus the authors of each individual study may write in a way that favours US. This has the potential to downplay the importance of other imaging modalities in the role of diagnosis. Additional biases may have occurred in our results as the precise order of investigations in the individual studies was oftentimes unclear and due to the qualitative nature of reporting US results, which either reports suspicion of a diagnosis or confirms suspicion. This made it difficult to determine a final diagnosis with complete certainty.

Most studies in our systematic search did not report US wave frequency, technique, machine model, or training grade of the administering clinician. However, we observed that ultrasonography was carried out in majority by surgeons (n =8), followed by radiologists (n =5), and emergency physicians (n =4). Two studies did not provide enough information for the administering clinician to be deduced. This has significance because studies suggest that clinician technique plays a significant role in the sensitivity and specificity of US use with children [7] and in the adult population,[8] affecting the practical effectiveness of ultrasonography. The authors (M.T, S.A-A) have also observed the importance of clinician technique from personal experience of ultrasonography use in paediatric hand clinics. The authors observed that whilst there is a learning curve in performing and diagnosing with US, its effectiveness and practicality as a diagnostic tool has been positive.

CONCLUSION

Based on the results of our study, ultrasonography is a valuable tool for tendon, blood vessel, and ligament injury and should be considered in the diagnosis of other pathologies. We consider that ultrasonography has utility as an early diagnostic step for paediatric hand injuries. With benefits of being a non-ionising and less expensive diagnostic modality, the use of US for clinical paediatric hand services may be a viable option for common use in the future. More research however should be conducted to produce guidelines on the use of US as a diagnostic modality in paediatric hand injuries to reduce diagnostic uncertainty and to reduce the cost of healthcare by eliminating unnecessary investigations to ultimately improve patient outcomes. Future studies should consider the effect of US frequency, technique, and clinician ability on US accuracy to understand its true effectiveness.

The author(s) declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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FIGURE LEGENDS

Figure 1. PRISMA flow chart of selection of studies for review.[9]

TABLE LEGENDS

Table 1. Table of diagnosis pathway in all patients.

Table 2. Table of ultrasonography diagnostic accuracy.

Table 3. Demographical and US data found in all studies.