Diagnostic imaging for elbow TRASH lesions in children and usefulness of ultrasonography using standard planes

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Fractures around the elbow in children should be carefully evaluated because the main portion is cartilaginous, and radiographs are not completely reliable. This study aimed to assess the diagnostic imaging for pediatric elbow fractures that require special attention and consider the usefulness of ultrasonography with seven standard planes for the diagnosis. Patients diagnosed with elbow fractures wherein TRASH (The Radiographic Appearance Seemed Harmless) lesions were evaluated retrospectively. The diagnoses on initial radiographs, final diagnoses, additional imaging excluding radiographs, and the treatments were investigated. The standard planes for ultrasonography to detect elbow fractures included an anterior transverse scan at the level of the capitellum and proximal radioulnar joint, an anterior longitudinal scan at the level of the humeroradial and humeroulnar joints, a longitudinal scan along the lateral and medial border of the distal humerus, and a posterior longitudinal scan at the level of the distal humerus. A total of 107 patients with an average age of 5.8 years (range, 0–12 years) at the time of diagnosis were included. Of 46 (43.0%) patients misdiagnosed at the initial radiograph, 19 (17.8%) needed additional treatments due to inappropriate initial management. Ultrasonography using the standard planes was useful for prompt diagnosis and appropriate treatment. Prompt and appropriate evaluation with ultrasonography can prevent the mismanagement of pediatric elbow injuries. Level of evidence: Level IV-retrospective case series. *J Pediatr Orthop B* 32: 557–564 Copyright © 2023 Wolters Kluwer Health, Inc. All rights reserved.

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Introduction

Pediatric elbow fractures comprise approximately 10–15% of all pediatric fractures [1,2], and the trauma mostly involves the application of violent force on the elbow in extension [3–5]. Most parts of the pediatric elbow joint are cartilaginous and obtaining proper radiographs is often difficult due to failure to follow instructions [6]; thus, pediatric elbow injuries should be carefully evaluated. Serious long-term complications, including loss of reduction, malunion, nonunion, heterotopic ossification, and neurovascular injury, may occur if severe osteochondral lesions around the pediatric elbow are not promptly diagnosed with the appropriate imaging techniques [5,7–12].

To promote awareness about pediatric elbow injury diagnoses and treatments, Waters *et al.* defined a small subset of serious injuries that were likely to be missed and could lead to serious long-term complications, known as 'the radiographic appearance seemed harmless' (TRASH) lesions [7]. Moreover, it was reported that a high level of suspicion and early imaging, such as ultrasonography, arthrogram, and MRI, are necessary for successful treatment. However, sedation is needed for young children undergoing an arthrogram or MRI, preventing most institutions from doing it promptly. Furthermore, the experience of the surgeon responsible for deciding whether to classify a pediatric elbow fracture as a minor fracture on a radiograph leads to discrepancies in the diagnoses.

This study aimed to investigate the clinical results of the TRASH lesions in our institution and identify which injuries were correctly diagnosed and treated. Moreover, this study aimed to establish a standard plane of ultrasonography that can detect TRASH lesions.

Methods

We reviewed the medical records of all cases of TRASH lesions using the International Classification of Diseases-10 codes in our center between 1996 and 2021. Inclusion criteria of this study, aside from the osteochondral injuries that Waters *et al.* [7] classified as 'Elbow TRASH Lesions', are osteochondral fractures with small fragments or no apparent fragments in the initial radiograph; patients with long-term complications caused by inadequate treatment or were assumed to have developed long-term complications if inadequately treated; and those with accurate medical records. In addition,

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the patients with a suspected but definitively uncertain diagnosis, those aged 16 years or more, and those with inadequate medical records, including radiographs, for the initial and final diagnosis were excluded.

The initial diagnosis from the radiograph, final diagnosis, and additional imaging [ultrasonography, arthrogram, computed tomography (CT), and MRI] conducted for the diagnosis, initial treatment, and additional treatment for the TRASH lesions or complications were investigated. Moreover, we assessed the utility of our ultrasonography technique [Aplio a Verifia with a high-frequency transducer (4.0–14.0 MHz); Canon Medical Systems Corp., Japan]. Ultrasonography for pediatric elbow fractures was sequentially acquired over seven standard planes, such as transverse scans of the distal humerus at the level of 1) the capitellum and 2) the proximal radioulnar joint; longitudinal scans of 3) the radiocapitellar and 4) humeroulnar joints; and the 5) lateral, 6) medial, and 7) posterior borders of the distal humerus. The children's comfort was maintained during the procedure by starting with the unaffected side and initially opening only the anterior side of the bandage dressing where the splint was already attached (Fig. 1). If adequate standard planes were not acquired due to the extremely swollen soft tissue of the elbow, the ultrasonography procedure was repeated over several days to confirm the presence of TRASH lesions.

The study was approved by the Osaka City General Hospital Review Board, and informed consent was obtained in the form of opting out.

Results

A total of 107 cases (32 girls and 75 boys) were included, with an average age of 5.8 years (0–12 years). The final diagnoses included two medial condylar humerus fractures, 18 transphyseal distal humerus fractures, one entrapped medial epicondylar fracture, 16 complex osteochondral elbow fracture-dislocations (including two lateral condylar avulsion shear fractures), three radial head fractures, 41 Monteggia fracture-dislocations, three humeral capitellar fractures, seven lateral condylar avulsion shear fractures, and 16 lateral condylar fractures (Table 1). Forty-six patients were misdiagnosed at the initial radiograph. Their diagnoses were reclassified as medial condylar humerus fractures ($n=2$), transphyseal distal humerus fractures ($n=10$), complex osteochondral elbow fracture-dislocations ($n=3$), a radial head fracture ($n=1$), Monteggia fracture-dislocations ($n=18$), a humeral capitellar fracture ($n=1$), lateral condylar avulsion shear fractures ($n=3$), and lateral condylar fractures ($n=8$). Due to inappropriate initial management, 19 patients needed additional treatments, which included 10 corrective osteotomies (eight Monteggia fracture-dislocations, one medial condylar humerus fracture, and one lateral condylar fracture), one open reduction and internal fixation (ORIF) (one lateral condylar fracture), one closed reduction with percutaneous pinning (CRPP) (one transphyseal distal humerus fracture) and seven closed reduction and cast immobilization (three Monteggia fracture-dislocations, four lateral condylar fractures). Fifty-eight cases needed additional imaging for a diagnosis (Table 1). All 19 patients who underwent ultrasonography examinations were correctly diagnosed.

Case reports

Case 1

A 7-year-old girl injured her elbow after falling from a stepladder. Although her elbow was severely swollen, her previous surgeon could not decide whether to follow a conservative treatment method with a cast or to perform surgery because of a small fragment found on the radiograph. Hence, she was referred to our hospital for treatment of her elbow fracture (Fig. 2). The obvious osteochondral fracture of the radial head was detected by a transverse scan of the proximal radioulnar joint and longitudinal scan of the radiocapitellar joint with ultrasonography (Fig. 3). We performed an ORIF using bioabsorbable pins (Fig. 4).

Case 2

A 6-year-old boy injured his elbow during gymnastics. He was misdiagnosed with a contusion at the previous hospital and was advised of observation. When his parents noted an anterior protrusion of his elbow, they consulted our hospital. A radial head dislocation was detected on the initial ultrasonography (Fig. 5), and we diagnosed it as a Monteggia fracture-dislocation with an ulnar plastic deformation on the forearm radiograph (Fig. 6). A corrective osteotomy was performed to treat the dislocation.

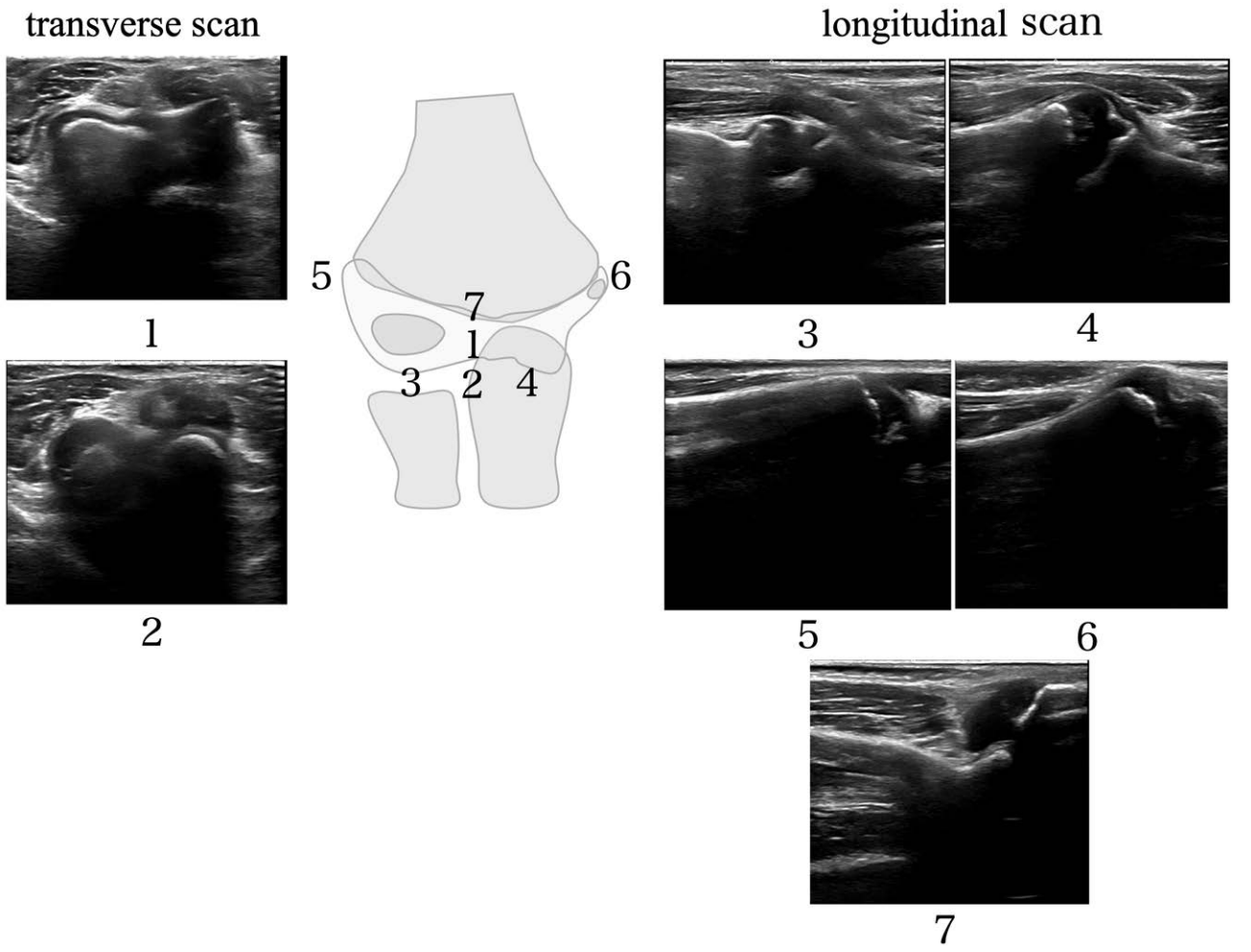
Case 3

A 7-year-old boy who injured his elbow after falling was suspected of having an avulsion fracture of the lateral condyle of the humerus. A splint was applied at the previous hospital, and the patient was advised of observation. As the fragment appeared to be displaced, his caregivers consulted our hospital (Fig. 7). Although the diagnosis was a lateral condylar fracture, intact cartilage on the hinges of the fracture was also detected by ultrasonography (Fig. 8). We assumed it to be stable and, therefore, applied a molded cast to his elbow. The diagnosis and cartilage hinges were later reconfirmed through an MRI (Fig. 9) because of the restrictions of the order of emergencies and sedation of the patient. A bony union was achieved with the cast (Fig. 10).

Discussion

It is difficult to diagnose osteochondral injuries around the elbow and lesions after the reduction of an elbow dislocation in children aged less than 10 years. Therefore, a high index of suspicion should be maintained, and additional imaging and aggressive surgical care should be performed for accurate diagnoses and treatments [8,9,13–17].

Fig. 1



Ultrasonography scanning planes. (1) Transverse scan of the distal humerus at the level of the capitellum, the important scanning plane, which determines if it is an intraarticular fracture or not (a medial condylar humerus fracture, lateral condylar fracture, transphyseal distal humerus fracture, humeral capitellar fracture, and lateral condylar avulsion shear fracture can be cited as differential diagnoses). (2) Proximal radioulnar joint. The shape of the radial head, congruence of the radio-ulnar joint, and interposition of fragments should be identified (Monteggia fracture-dislocations and radial head fracture can be cited as a differential diagnosis). (3) Longitudinal scan of the radiocapitellar joint. An intra-articular hematoma, osteochondral fractures including the epiphyseal growth plates, and congruence of the joint should be identified (Monteggia fracture-dislocations, lateral condylar fracture, transphyseal distal humerus fracture, humeral capitellar fracture, and radial head fracture can be cited as differential diagnoses). (4) Humeroulnar joint. An intra-articular hematoma, osteochondral fractures including the epiphyseal growth plates, and congruence of the joint should be identified (a medial condylar humerus fracture, transphyseal distal humerus fracture, trochlea of humerus fracture, and coronoid process fracture can be cited as differential diagnoses). (5) Lateral border of the distal humerus. Osteochondral fractures, including the epiphyseal growth plates and enthesis of the lateral ligament, should be evaluated (a lateral condylar fracture, lateral condylar avulsion shear fracture, and transphyseal distal humerus fracture can be cited as differential diagnoses). (6) Medial border of the distal humerus; likewise, osteochondral fractures, including the epiphyseal growth plates and enthesis of the lateral ligament, should be evaluated (medial condylar fracture, medial epicondyle fracture, and transphyseal distal humerus fracture can be cited as differential diagnoses). (7) Posterior to the distal humerus, if possible, without stress to the patient; an intra-articular hematoma was easy to determine, and osteochondral fractures should be evaluated. In each scanning plane, we confirmed if there were osteochondral lesions with the incongruence of the joint.

Past reports have noted that essential findings could be missed if the diagnosis relied only on a radiograph, especially when working in busy emergency clinics [7,8]. Waters *et al.* reported these injuries as 'TRASH lesions' and advocated the importance of prompt diagnosis and successful treatment before complications arise [7].

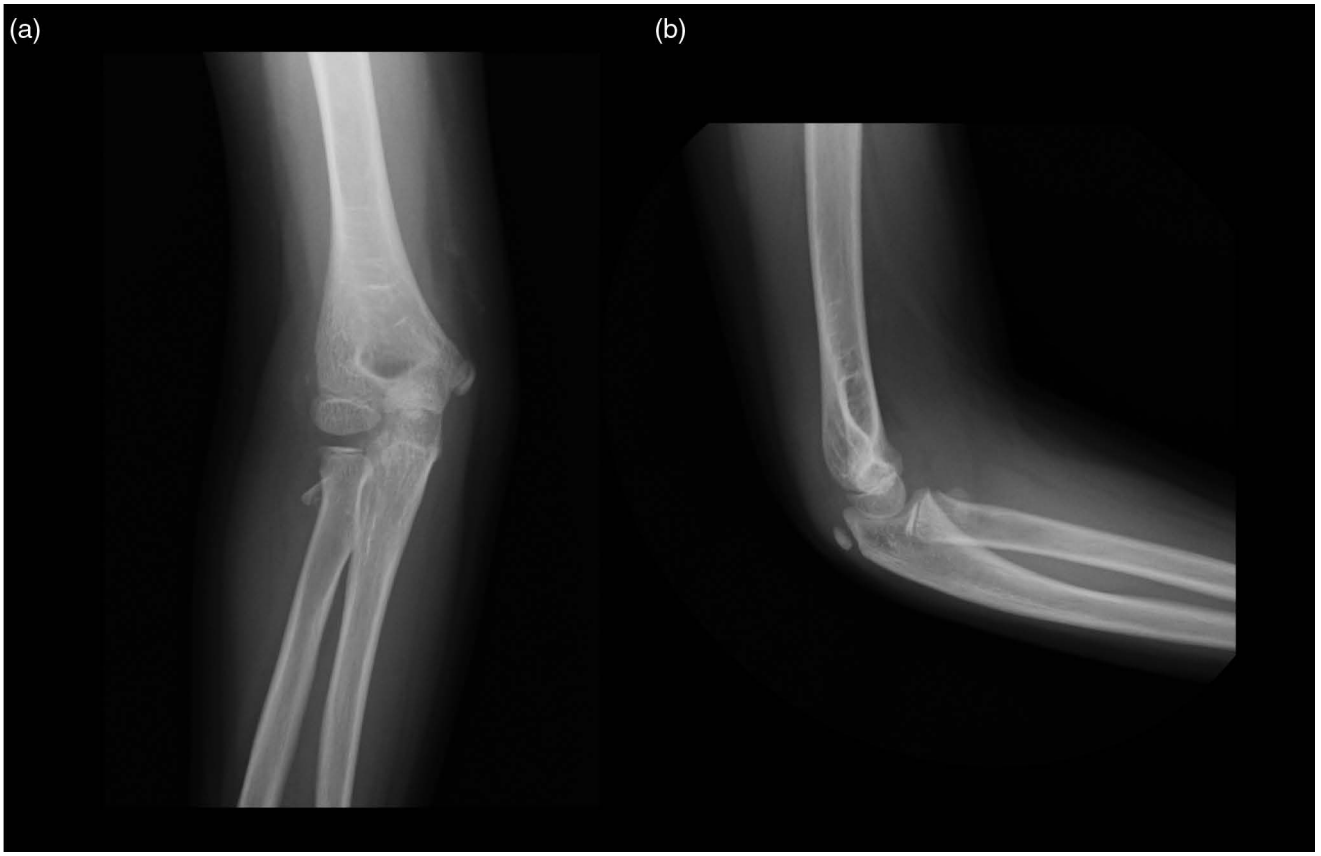
In this study, 46 cases were misdiagnosed after the initial radiograph, including cases with medial condylar humerus fractures, transphyseal distal humerus fractures, complex osteochondral elbow fracture-dislocations, radial head fractures, Monteggia fracture-dislocations, humeral capitellar fractures, lateral condylar avulsion shear fractures, and lateral condylar fractures. The 19 cases that received additional treatments included cases with medial condylar humerus fractures, transphyseal distal humerus fractures, Monteggia fracture-dislocations, lateral condylar avulsion shear fractures, and

Table 1 **Summary of clinical cases**

	Final diagnosis	Misdiagnosis[a]	Additional imaging			
			MRI	CT	Arthrogram	Ultrasonography
Unossified medial condylar humerus fractures	2	2	2	1		
Transphyseal distal humerus fractures	18	10	6	1	6	2
Entrapped medial epicondylar fractures	1			1		
Complex osteochondral elbow fracture – dislocations below the age of 10 years	16	3	3	6	1	2
Radial head fractures	3	1		1		1
Monteggia fracture dislocations	41	18	6	9		4
Humeral capitellar fractures	3	1		2		1
Lateral condylar avulsion shear fractures	7	3	2	4		1
Lateral condylar fractures	16	8	5	2	2	8

CT, computed tomography.
[a]Diagnosis at first X-ray.

Fig. 2



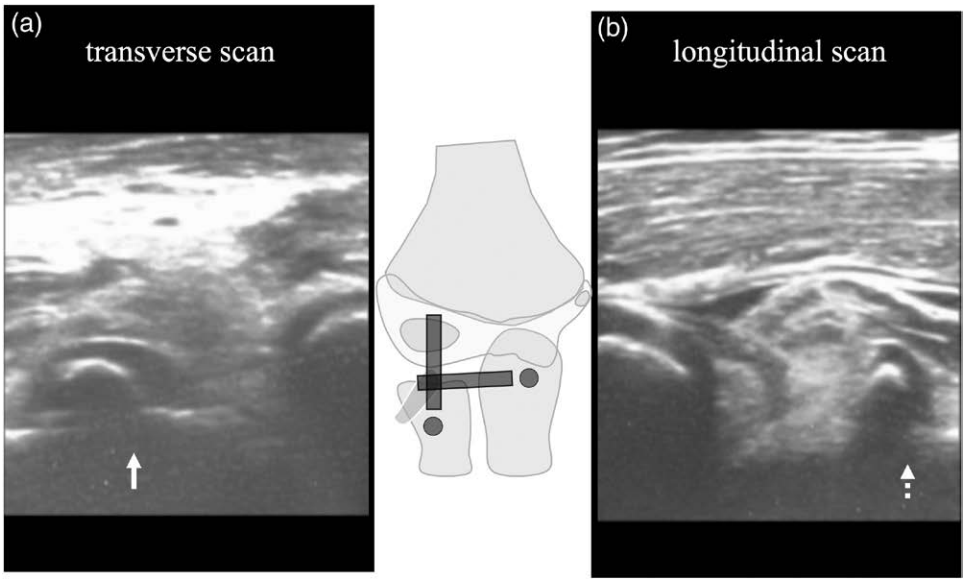
Initial radiograph. (a) Antero-posterior and (b) lateral views showing a small fragment near the radial head (arrow).

lateral condylar fractures. Hence, these fractures should be given particular attention during diagnosis and treatment.

Treatment options for these fractures to prevent dire consequences have been reported. The medial condylar humerus fractures are mostly selected for conservative treatment for Kilfoyle grades I and II; however, grade III requires ORIF [18,19]. The recommendations for transphyseal distal humerus fracture treatment differ among surgeons, but CRPP is widely accepted [20,21]. The early diagnosis of Monteggia fracture-dislocations is essential for their treatment. If it is detected early, a closed reduction of the radial head with correction of the ulna bow is a viable option [8]. Lateral condylar fractures, which are unstable and have more than 2-mm displacement, are indications for CRPP or ORIF [22,23]. Nevertheless, the accurate reduction and fixation with the early diagnosis require careful attention.

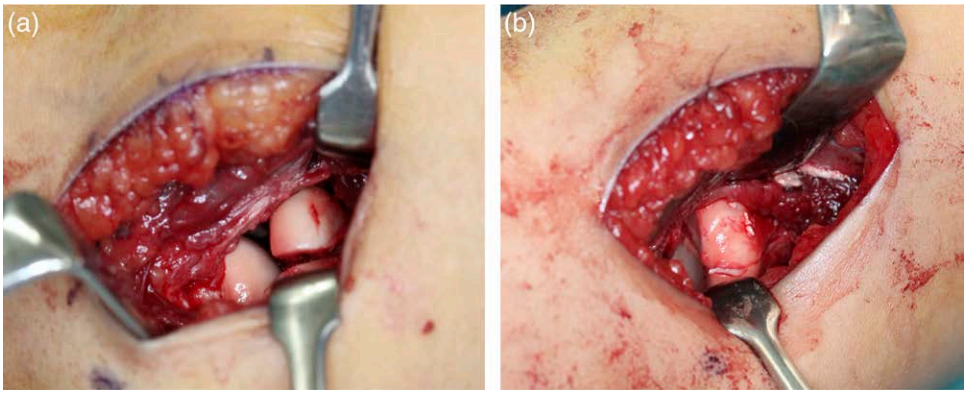
Additional imaging, ultrasonography, arthrogram, and MRI are more useful than CT because osteochondral

Fig. 3



Ultrasonography. (a) Transverse scan of the distal humerus at the level of the proximal radioulnar joint. (b) Longitudinal scan of the radiocapitellar joint. The arrow shows that the radial head was not round, which indicates radial head fracture. The dotted arrow shows the separation of the radial head.

Fig. 4

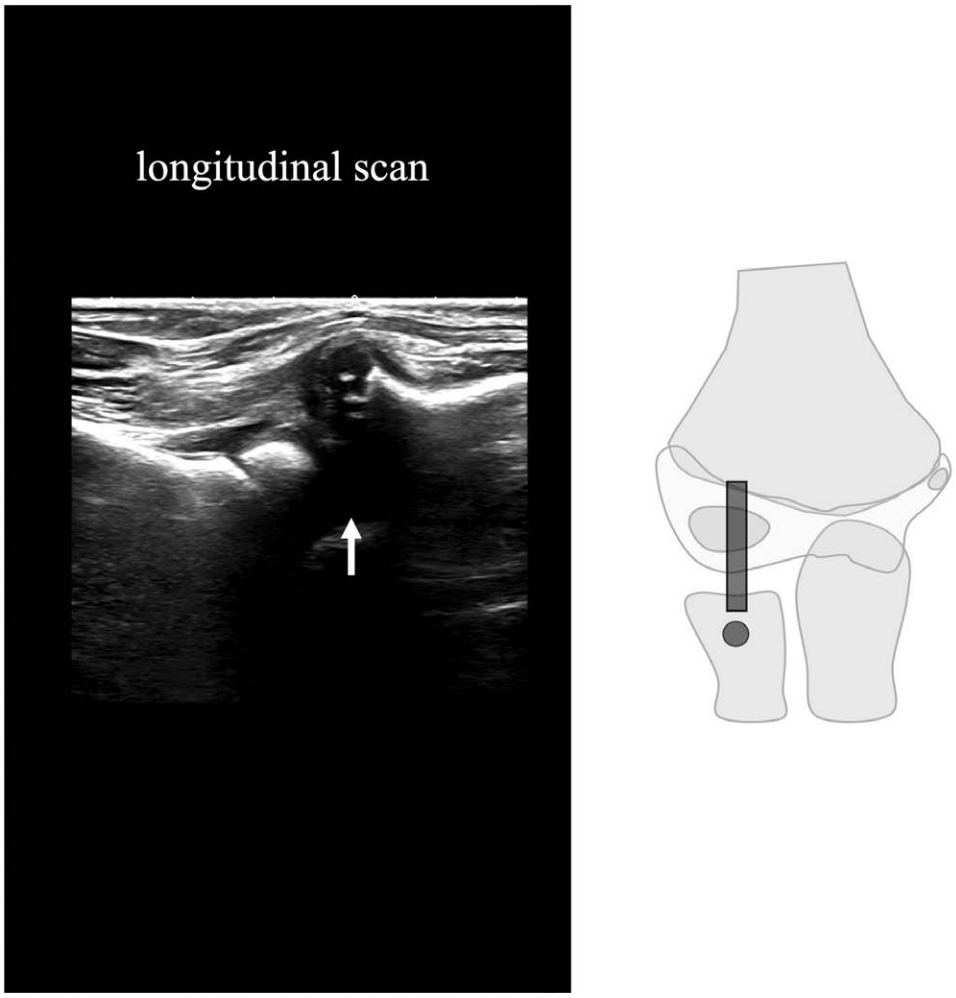


Intraoperative appearance. (a) Pre-fixation of a radial head fracture. (b) Post-fixation with bioabsorbable pins from the fragment of the radial head.

lesions are easier to evaluate using these modalities in children with unossified elbows. However, there are several limitations of arthrogram and MRI examinations, which include the restriction of an emergency order of these inspections and the necessity of sedation in many institutions. Although ultrasonography, which is rapidly developing, can evaluate TRASH lesions because it allows for high-resolution imaging of the osteochondral fragment without sedation, properly assessing lesions through ultrasonography images is technically difficult, and the accuracy of diagnosis depends on the examiner's skill [24]. In this study, we conducted ultrasonography scans and diagnosed osteochondral lesions using seven standard planes (Fig. 1). We acquired these standard planes as rapidly as possible. Even elbow injuries with TRASH lesions could be detected using ultrasonography.

In each case diagnosed by ultrasonography, we prevented the chance of misdiagnosis and selected the appropriate treatments. Several studies have shown the usefulness of ultrasonography for evaluating pediatric elbow fractures to decide the course of treatment; ultrasonography compares favorably with other imaging methods like arthrograms [25–27]. The lateral condylar fracture in Case 3 was determined to be stable with intact cartilage hinges and healed with a molded cast without any complications. As described, while the visualization of cartilage was seemingly vague in the radiographs, we detected it accurately

Fig. 5

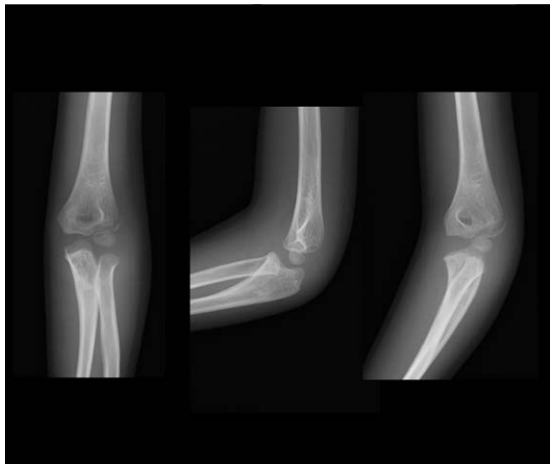


Ultrasonography. Longitudinal scan of the radiocapitellar joint. The arrow shows the radial head dislocated anteriorly to the capitellum of the humerus.

Fig. 6

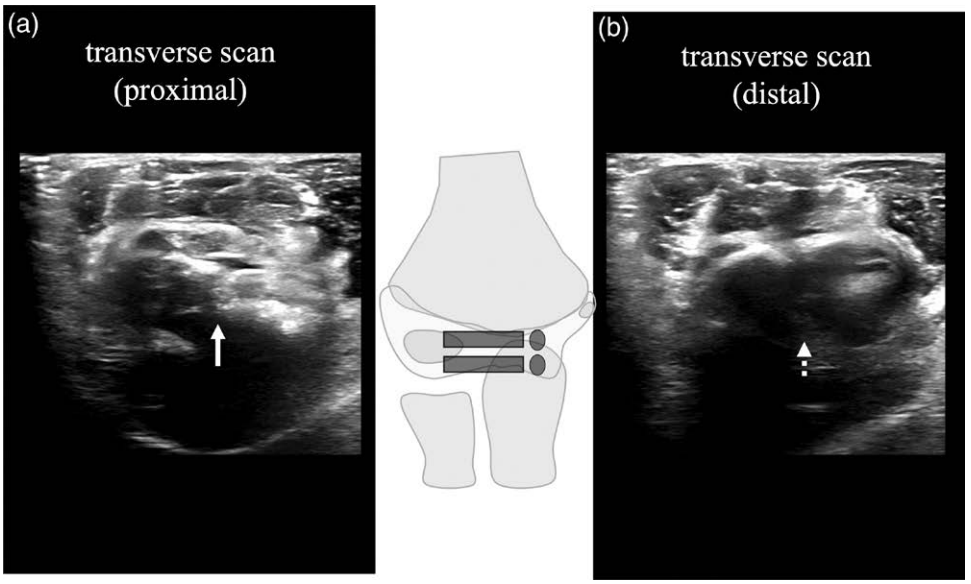
Radiograph from the primary hospital. A lateral view shows the radial head anterior dislocation and ulnar anterior bowing.

Fig. 7



Radiograph from the primary hospital. Anteroposterior, lateral, and oblique views show the maximum translation of the fracture to be 3 mm.

Fig. 8

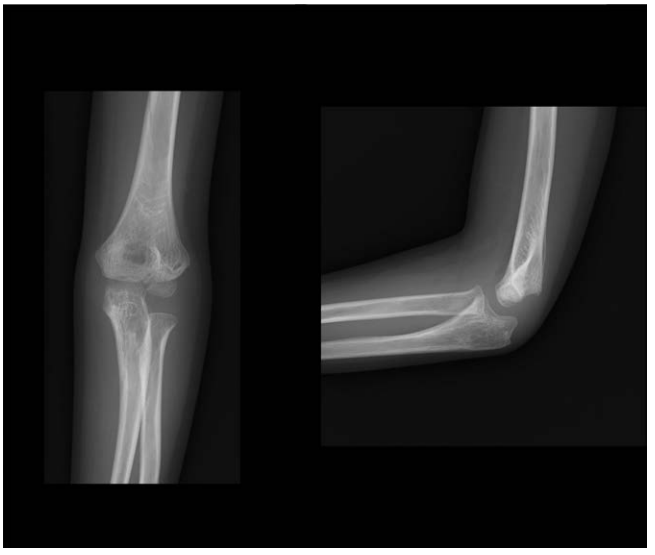


Ultrasonography. A transverse scan of the distal humerus (a) at the level of the capitellum (the arrow shows the separation of the intra-articular cartilage) and (b) at the level of the end of the distal humerus cartilage (the dotted arrow shows an intact cartilage hinge).

Fig. 9

T2-weighted MRI. The arrow shows a clear fracture line at the level of the capitellum but an intact cartilage hinge at the level of the end of the distal humerus.

Fig. 10



Radiograph at 8 weeks post-injury showing bone union in the lateral condylar fracture.

using ultrasonography. This led to favorable outcomes in cases of stable lateral condylar fractures by treatment with a molded cast or CRPP after verifying the intact cartilage hinges.

Due to the advancement of high-resolution imaging with ultrasonography, we can appropriately evaluate osteochondral lesions in children. An increase in the availability of ultrasonography will be essential not only for detecting TRASH lesions but also for determining the appropriate treatment strategy for pediatric osteochondral fractures.

Since the condition of suspicion of the TRASH lesions is the most important, one should always remember that careful examination and interpretation of plain radiographs are the best way not to miss these lesions. Particularly, the Monteggia fracture-dislocation in Case 2 could have been accurately diagnosed if standard radiograph imaging had been performed. Standard radiograph imaging of the limbs includes radiographs of the joints above and below the injury (in two views) and comparison with the contralateral side. The seven-standard plane ultrasonography method would be useful for detecting these fractures when inexperienced surgeons or radiologists suspect some elbow injuries but cannot diagnose them with a plain radiograph. However, ultrasonography should not replace appropriate radiography and interpretation.

In conclusion, prompt and appropriate evaluation through additional imaging techniques like ultrasonography, arthrogram, and MRI, in addition to aggressive surgical care, can prevent severe complications of elbow TRASH lesions. Furthermore, ultrasonography evaluations of lesions with standard planes can be acquired in children without difficulties.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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