

Distal Radius Fractures in Children

Christian Tingström

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Läkarprogrammet
Examensarbete VT15
031-786 30 81
examensarbetet.lakare@gu.se

Ett forskningsprojekt i samarbete med Barnortopederna vid Sahlgrenska Sjukhuset, Drottning Silvias Barnsjukhus, Östra Sjukhuset. Projektet syftar till att undersöka i vilken utsträckning ultraljud skulle kunna användas på Barnakuten för avancerad triage vid misstänkta distala radiusfrakturer.

**Distal Radius Fractures in Children:
Can point-of-care ultrasonography decrease
the need for radiographs?**

Master thesis in medicine

Christian Tingström

Supervisor: Jón Karlsson, Professor

Examiner: Kristian Samuelsson, MD PhD



UNIVERSITY OF GOTHENBURG

Programme in medicine: Gothenburg, Sweden 2015

Emergency Department, Sahlgrenska University Hospital, Drottning Silvias
Barnsjukhus, Östra Sjukhuset, Gothenburg

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ABSTRACT

Master thesis, programme in medicine

Title

Distal radius fractures in children: Can point-of-care ultrasonography decrease the need for radiographs?

Author and year

Christian Tingström, 2015.

Institution

Emergency Department, Sahlgrenska University Hospital, Drottning Silvias Barnsjukhus, Östra Sjukhuset, Gothenburg.

City and country

Gothenburg, Sweden.

Background

Pediatric fractures are very common and many of these involve the distal radius. Juvenile bones are different in structure compared to adults and display a different panorama of injuries and treatments. Radiographs are the gold standard, but recent studies have shown that ultrasonography can be used to diagnose skeletal injuries.

Purpose

We aimed to see if point-of-care ultrasonography performed by physicians unpracticed to ultrasonography was as good as radiographs in finding and differing between complete and incomplete distal radius fractures. The research question was to which extent ultrasonography

could decrease the need of radiographs? Possible advantages (time, economy and radiation) in using fewer radiographs in favor of ultrasonography were discussed.

Study design

Comparative study.

Methods

The data was based on a population, three to sixteen years old, which attended children's medical services within three days after trauma. Study physicians formed their opinion on if a fracture was present after ultrasonography examinations and radiographs respectively, the ultrasonography assessment was blinded to the radiographs. Cross tabulation with Cohen's Kappa and One-sample T-test was used in IBM® SPSS Statistics to analyze inter-rater agreement.

Results

A total of sixty-nine patients were included in the study. The study physicians managed to correctly assess fifty-eight out of sixty-nine (84%) (95% CI, 75-93) cases compared with radiograph assessment. The study physicians managed to diagnose all fractures with an overestimation by two but classified five complete fractures as incomplete.

Conclusion

Point-of-care ultrasonography performed by physicians without former education on ultrasonography has a big potential in reducing the number of radiographs needed. However, further research is recommended to establish more accurate criteria when differing between incomplete and complete fractures.

Key words

Distal radius fractures, children, ultrasonography, point-of-care ultrasonography.

BACKGROUND

Development, anatomy and physiology of the juvenile forearm

Radius and ulna are two of the upper extremity's long bones. Long bones grow through endochondral ossification (1), which means that there is a prenatal model created of cartilage. This cartilage model is later progressively replaced by bone from a number of centers, called primary and secondary centers of ossification (see "Figure 1")(1).

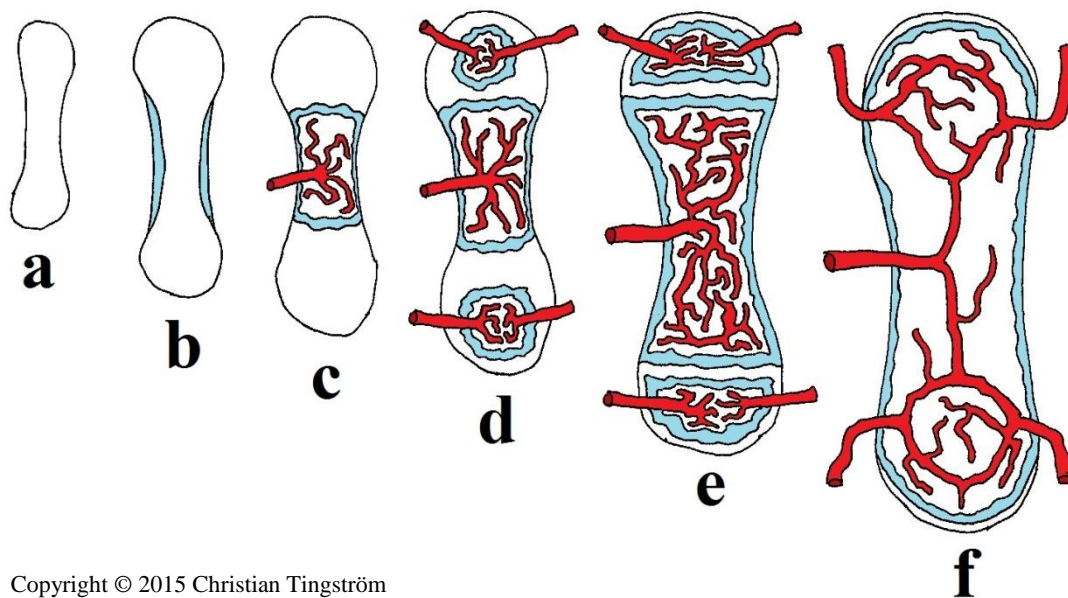
The primary center of ossification normally appears prenatally in most long bones and starts with a calcification of the central surface of the cartilage model (1). blood vessels then penetrate into the central part of the cartilage model thus providing ossification from the central part and out (1). Through the blood vessels a variety of cells have the opportunity to enter the developing bone, of importance are those who create the final bone structure and those who reabsorb the broken down cartilage (1). The primary center of ossification creates what is later called the diaphysis.

The secondary centers on the contrary appears after birth and it begins in a similar way with blood vessels entering both ends of the cartilage model providing ossification of the ends which will later be called the epiphyses (1). Since both the primary and the secondary centers are created early in the developmental period (see "Table 1") there need to be a space between them in order to maintain growth of the long bones, this space is called the physis and consist of the remnant cartilage from the original model (1).

A big advantage of using a cartilage physis as a growth medium instead of bone is the growth rate. Since bone is hard, and slowly remodel, its growth rate is about some millimeters a year, but using cartilage as a growth medium instead results in several centimeter a year (1). Its

extensive growth rate is furthermore held up by a big amount of blood vessels entering the bone, providing nutrition almost solely from the ends of the bone (1).

The long bones are done growing when both the proximal and the distal physes are closed (1, 2)(see "Table 1"). After that long bones only remodel and restructure according to for example physical load and hormonal responses. "Figure 1" shows the development of endochondral bones in a general outline.



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Figure 1, The development of long bones: Cartilage model (a), central ossification (b), creation of primary center of ossification with entrance of blood vessels (c), creation of secondary centers of ossification with entrance of blood vessels (d), growth and creation of the proximal and distal physis (e) and closure of the physes with creation of articular cartilage (f).

The proximal physes are created later and closed earlier than the distal physes but different growth rates are observed in the radius and ulna. In the radius the distal physis contributes with 75% of total growth and the proximal physis contributes with the remaining 25%. The condition is almost reverse in the ulna, where the distal and proximal physes contributes with 20% and 80% respectively (2).

The centers of ossification appears on different occasions during the developmental period and also differs between genders (1, 2). “Table 1” presents in what year after birth secondary centers appear and physes close in boys and girls in average (2).

Table 1, Secondary centers of ossification appearance and closure of physes in the radius and ulna in males and females respectively. Given numbers are average values for all categories.

Bone: Sex	Distal secondary center appearance	Distal physis closure	Proximal secondary center appearance	Proximal physis closure
Radius: Male	1 year	19 year	5 year	15-17 year
Radius: Female	1year	17 year	4 year	14-15 year
Ulna: Male	6 year	19 year	10 year	14-17 year
Ulna: Female	5 year	17 year	8 year	14-15 year

There are some important difference between the skeletal anatomy of children and adults.

Adult long bones are constructed through two major structure types: cortical bone and cancellous bone (1). Both structures are composed of the same components but differ in density and proportions. Cortical bone is a compact structure whereas cancellous bone is a porous structure organized in networks to decrease weight and increase the area exposed to surrounding tissue. Therefore cancellous bone has immense contact with nutrition through blood and hence has a great capacity of remodeling. Compact bone is very slowly remodeled due to low exposure to surrounding tissues. The bone tissue, independent of type, are organized in layers with collagenous fibers perpendicular to one another (lamellar bone)(1).The importance in having two different types of structures lies in its ability to tolerate as great load as possible and at the same time have the lowest possible weight (1). This also means that the adult bones cannot tolerate such a big deformation before they fracture (3).

In children however bones present a greater plasticity and elasticity partly because of a lower degree of calcification. This means that the bones can withstand a greater angular force before

they fracture. Instead such forces sometimes lead to deformities of the bones through buckling, creating what is often referred to as an infraction or a Torus fracture (3).

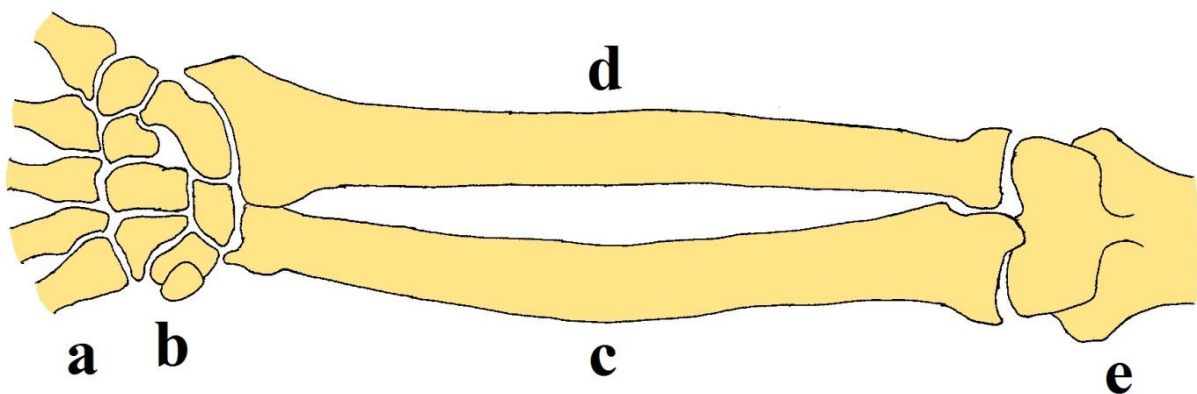
Another difference between juvenile and adult bones is the thickness of its surrounding periosteal sleeve (3). Children have a very thick periosteal sleeve that serves as a support when creating and remodeling bones (1, 3, 4). Moreover, the periosteal sleeve is a tight and rigid structure in children that mechanically helps the bone not to fracture when put under angular load. This periosteal sleeve then diminishes in thickness as the child gets older.

A third important factor is the relative rigidity and strength of bones, muscles and ligaments in joints. Children have as noted more plastic and elastic bones than adults but on the other hand children's ligaments are stronger. Therefore a force that normally gives a luxation in adults instead contracts a fracture in children (1, 4).

When a bone is fractured it heals quite similar to other tissues. The fracture leads to exposure of both cell bound factors and diffusing factors that affect immature connective tissue cells (1). These connective tissue cells then differentiate towards bone or cartilage cells and migrate to the site of the fracture to induce the creation of new bone tissue (1). However, when repairing fractures there is a faster creation of bone tissue than when the bones are initially created (1). This implicates that the structure of the newly created bone tissue are of the woven type rather than the lamellar type (1). In extension this leads to a bone tissue that is weaker than the non-fractured bone tissue since the woven bone is not organized in layers with perpendicular directions of the reinforcing collagen fibers (1). Gradually due to loading the bone tissue will however remodel towards a more organized structure with mostly lamellar bone thus slowly creating a stronger bone (1).

The periosteal sleeve is also of help in healing the fracture since it both helps by holding the fragments in place mechanically and has hypertrophic abilities that can help regenerating bone tissue and thus shorten healing time (1).

The speed with which healing of a fracture is done in a child also very much depend on how old the child is (1). A younger child heals its fracture faster than an older child or adult. Data suggests that femur fractures for example heals over two weeks in a newborn but over six to eight weeks in an older child and over about three month in an adult (1). If the child is younger than eight to ten years old remodeling of the bone is nearly always done perfectly but the healing of older children's bones more commonly fail on that point (5).



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Figure 2, The anatomy of the forearm: Proximal part of metacarpal bones (a), carpal bones (b), ulna (c), radius (d) and distal part of humerus (e).

The wrist is formed by a number of bones (see "Figure 2"). Those are the two long bones of the forearm and the eight carpal bones of the hand, the most proximal four in particular. These bones contribute to a wide range of movement of the wrist. The carpal bones have little individual movement but together they are creating a series of small joints in between themselves that lead to bigger movement ranges. The four most proximal carpal bones articulate with the cartilage surface on the distal ends of the radius and ulna (radius in

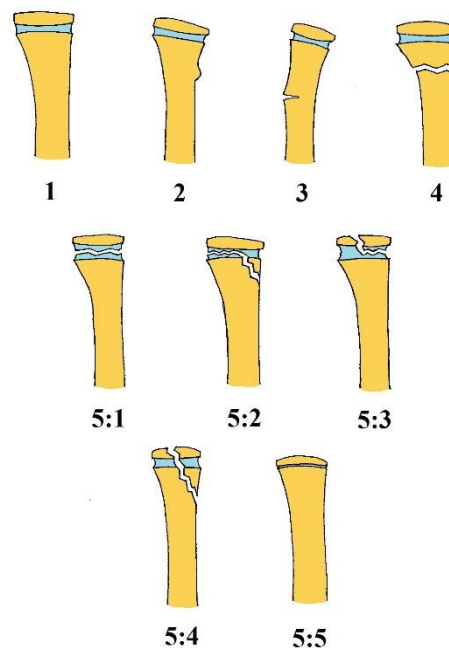
particular). This creates bigger range of movement in the wrist that accounts for the major part in both flexion/extension and radial/ulnar deviation. The forearm bones are fixed regarding movement in the frontal plane. The ulna (olecranon) embraces the distal humerus cartilage surface and cannot rotate while the radius (lateral to ulna) is able to rotate in its position. This gives the wrist its ability to pronate and supinate because when doing so the radius can cross over the ulna (pronation) or remain parallel (supination). During pronation and supination the radius slides on the cartilage surface of the distal ulna in a circular movement in what is called the radioulnar joint. This crossing over feature also gives the elbow the possibility to flex or extend at all time, independent of the position of the hand.

Panorama of injuries and their causes

Musculoskeletal injuries are very frequent in the children's emergency departments and fractures play an important role counting for approximately 20% of all patients (6). A big portion of these cases present fractures in the distal forearm after trauma (2, 7). Some data suggest that more than 30% of all child fractures are located to the forearm (1) and some data suggests between 20% and 30% (5).

Trauma to the forearm can lead to a variety of conditions ranging from no skeletal damage to total fracture of the radius, the ulna or both. It is sometimes difficult to determine whether a fracture is present or not since all types of injuries can come with swelling of the forearm, making it hard to clinically reveal deformities of the bones. Normally injuries of the distal forearm bones are classified as infractions, greenstick fractures, total fractures involving the metaphysis or the epiphysis together with physeal fractures classified according to the Salter-Harris Classification (SH)(see "Figure 3" and "Table 2").

Falling on an outstretched arm is by far the most common cause of pain in the distal forearm (2, 7). Over the last 40 years this mechanism has increased by approximately 40% since sports and other physical activities has become a bigger part of children's spare time (7). Other injury mechanisms include knock on the hand and arm with various sports material such as balls, bats or sticks. Moreover collisions or simply falling without an outstretched arm can result in pain in the distal forearm and wrist. Since all mechanisms referred to above are caused by low energy traumas it is likely to assume low energy trauma is responsible for the biggest portion of all distal radius fractures. High energy traumas can of course also result in distal radius fractures but in those cases it is more likely, compared with low energy traumas, that the distal radius fracture is not isolated.



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Figure 3, A presentation of distal radius fractures in a general outline: No fracture (1), infracture (2), greenstick fracture (3), metaphyseal fracture (total)(4) and physeal fracture (SH1-5)(5:1-5).

Since the ulna is responsible for the stability of the forearm with its situation as fixed with one direction in the elbow joint and the radius is responsible for handling forces projected through

the hand, it is easy to see why the radius is more frequently injured than the ulna. As well as falling on an outstretched hand all movement of the wrist (see “Development, anatomy and physiology of the juvenile forearm” page 5) will create a force on the radius and if a skeletal injury is present pain will most certainly arise.

Standard procedure for diagnosis and treatment in the emergency department

Normally trauma to the forearm with resulting pain or discomfort is handled through clinical examination and radiographs. Before clinical examination a basic medical history is obtained with special focus on the mechanism of injury. The clinical examination includes inspection of possible swelling or angulations of the forearm establishing that there is no pain over the clavicle as well as shoulder and the brachium. The examining physician also tries to rule out pain in the elbow (by palpating the medial and lateral epicondyles and the olecranon), proximal radius (by palpating the head of the radial bone) and bones of the hand (by palpating the metacarpal bones and the carpal bones together with examination of the scaphoid bone). After that flexion and extension in elbow and wrist are tested together with pronation and supination of the hand to investigate if there is pain and in which locations. Furthermore the examining physician check the sensibility, mobility and capillary functions of the hand, called a distal status.

When the clinical examination is complete the patient undergoes a radiographic examination. The radiograph is the gold standard for finding fractures and deciding treatment for this type of injuries and an overwhelming majority of the distal forearm pain cases are examined through radiographs. In the Emergency Department, Sahlgrenska University Hospital, Drottning Silvias Barnsjukhus, Östra Sjukhuset, Gothenburg orthopedists and assistant physicians normally decides treatment based on their own assessment upon the radiographs of the distal radius, without reading the radiologist’s report.

The quality of radiographs can be expected to be very high. This is because the wrist is a relatively tiny target with not much surrounding soft tissue. In spite of the lowered radiation level compared to examining adults the wrist constitutes a relatively clear target and gives the opportunity of high quality images. The size of the wrist gives more detailed images.



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Figure 4, The normal plaster splint used on incomplete fractures.

Depending on the findings of the clinical examination combined with the radiographs a series of outcomes are possible. Usually if a fracture is present the radius is involved, sometimes both radius and ulna are involved and more rarely only the ulna is involved.

Table 2, Possible fracture types of the distal radius and descriptions to match.

Fracture type	Findings in addition to pain and possible swelling of soft tissue or deformity
Infraction	The trauma has forced the bone to compress on either or both the volar and dorsal side. No discontinuation of the bone cortex is seen. If only one side is bent the other side is normal.
Greenstick fracture	The trauma is big enough to create a discontinuation in the bone cortex on either the volar or the dorsal side. The other side is normal or bent but with continuation of the bone cortex. The thick periosteal sleeve can help keeping the bone/fragments in place.
Metaphyseal fracture	Total fracture of the bone on a metaphyseal level. Like the greenstick fracture the fragments can be held in place by the thick periosteal sleeve.
Physeal fracture	Total fracture of the bone engaging the physis. In addition to that the epiphysis and the metaphysis can be involved too. The physeal fractures are classified according to the Salter Harris classification system(4). <ul style="list-style-type: none"> • SH I: Fracture only engaging the physis. • SH II: Fracture cutting through the physis and metaphysis. • SH III: Fracture cutting through the physis and epiphysis. • SH IV: Fracture cutting through the metaphysis, physis and epiphysis. • SH V: Compression of the physis.

One of the differences in treating younger or older children is that different levels of deformity count as acceptable. “Table 3” shows which angulations are normally considered acceptable. If the deformity exceeds the acceptable level reposition is normally needed (1, 4, 8). Reposition can be performed in general or local anesthesia.

Table 3, Acceptable deformity and displacement of the distal radius fractures for three groups of patients.

Deformity	<8-10 years old	>8-10 years old	Adult (comparison)
Dorsal angulation	<20-25 degrees	<15-20 degrees	<20 degrees
Volar angulation	<10 degrees	<5-10 degrees	<20 degrees
Lateral displacement	<½ bone width	<¼ bone width	<4 mm

”Table 4” gives an overview of how fractures of all kinds in the distal radius, the distal ulna or both are treated (1, 2, 4, 8, 9). A regular cast can be seen in ”Figure 4”. The difference between the younger and the older group of children is that the younger can normally use the shorter alternative of immobilization while the older children are usually in need of the little longer alternatives (8). Also the localization of a fracture is important hence a more proximal fracture need a longer cast treatment (4).

Table 4, Treatments and control regimes for three groups of patients and the different types of fractures. If not specified, the fracture has acceptable deformity.

Fracture type	<8-10 years old	>8-10 years old	Adult (comparison)
Infraction	Elastic tubular bandage or 3-4 week plaster splint that is taken off in the home. follow-up.	3-4 week plaster splint that is taken off in the home. follow-up.	-
Greenstick fracture	3-5 week plaster splint that is taken off in the home. No follow-up.	3-5 week plaster splint that is taken off in the home. No follow-up.	-
Metaphyseal fracture with acceptable angulations	Semi circular cast. Radiographic control 7-10 days.	Semi circular cast. Radiographic control 7-10 days.	3-4 week plaster splint that is taken off during revisit. Radiographic control. Elastic binding can be used for comfort after that.
Physeal fracture without dislocation	3-4 week Semi circular cast that is taken off in the home. No revisit.	3-4 week Semi circular cast that is taken off in the home. No revisit.	-
Physeal fracture with acceptable angulation	3-4 week Semi circular cast. Radiographic control 5-7 days.	3-4 week Semi circular cast. Radiographic control 5-7 days.	-
Inacceptable angulations	Possibly reposition or surgery. Contact an orthopedist.	Possibly reposition or surgery. Contact an orthopedist.	Possibly reposition or surgery. Contact an orthopedist.

All pediatric fractures can be divided into subgroups depending on their treatment. This is shown in "Table 5".

Table 5, Fractures in subgroups depending on their treatment.

Subgroup by treatment	Fractures
No treatment or elastic tubular bandage Cast that is taken off in the home after 3-4 weeks, with no control radiograph or revisit	No fracture. Infractions and greenstick fractures with acceptable deformity. Physeal fractures without dislocation.
Possible reposition or surgery, cast and control radiograph together with revisit	Metaphyseal, epiphyseal and physeal fractures. All fractures with unacceptable deformity.

Possibilities of using ultrasonography in examining bones

There are some studies on the subject, most of them written in the last 15 years. When it comes to articles about ultrasonography as a diagnostic tool for examining bones in general

and distal radius (and ulna) in particular, the great majority of studies are produced in the last five years (2010 onward)(10-20). This indicates that there should be evidence on the subject available. However, most of the studies have very varying settings. “Table 5” presents a summary on the current evidence on distal radius diagnostics using ultrasonography.

Table 6, Summary on the current evidence on diagnostic ultrasonography in distal radius fractures

Factors to compare	Summary of the studies
Patients: Number and age	The number of patients included were very varying, from 26 to 212. The patients included also differed in age from 0-2 years old up to 12-25 years old.
Bones: Types	Most studies have focused on the distal radius even though some of them also have included all sorts of long bone injuries. One or two studies have set their limits to injuries in all bones.
Physicians: Number, role and experience	The authors have either performed the study with experienced ultrasonographers or do not present their experience at all. Only Patel D et al. present a study where physicians without any experience of ultrasonography conduct the examinations. Even the number of physicians varies a lot which could mean that they have different experience of ultrasonography. Most studies used pediatricians; however, some studies used radiologists or the authors themselves performed the examinations.
Ultrasonography: Introduction	The most common setting was that study physicians did get an introduction to ultrasonography beforehand during half an hour to two hours. Some studies had no previous introduction and in one or two the study physicians went through a licensed education.
Statistics: Sensitivity and specificity	The sensitivity and specificity were overall high. Mean sensitivity was 93.9% (73%-100%) and mean specificity was 94.5% (69%-100%).

From this summary one can conclude that many studies have tried to show how ultrasonography could be used to display distal radius fractures. Only one of the studies, however, involve physicians without former ultrasonography experience in performing the ultrasonography examinations and the rest do not show what experience the physicians have in ultrasonography. This is in one way good because it implicates that ultrasonography can be a sufficiently good tool to find and categorize distal radius fractures. It is also a problem because most physicians working in the emergency department have very little or no

experience in performing ultrasonography examinations. Sensitivity and specificity are overall high but they are expected to be even higher if only distal radius is studied. Some studies (Weinberg E R et al., Waterbrook A L et al. and Hübner U et al. for example) included all long bones or all bones and got the lowest sensitivity and specificity results (10, 17, 20).

INTRODUCTION

None of the previous studies (see “Possibilities of using ultrasonography in examining bones” page 15) were assembled the way this study needed to be, in order to explore if ultrasonography can be used as a kind of advanced triage in order to decrease the need for radiographs. Three differences between this study and previous research are:

- This research aimed to focus only on the distal radius.
- This research aimed to simulate the conditions in an emergency department, where physicians without former experience in using ultrasonography work.
- This research aimed to find if point-of-care ultrasonography can function as an advanced triage method to sort out which patients need a radiographic examination and which patients only need to receive a cast or no treatment at all.

The following section is meant to present reasons on why this research is motivated, both in the patient’s and the emergency department’s perspective.

To begin with, the lead times in the emergency department and radiology department are of importance. The average for the entire emergency department (not only orthopedics) when it comes to waiting time before radiographic examination is currently forty-seven minutes in the Emergency Department, Sahlgrenska University Hospital, Drottning Silvias Barnsjukhus, Östra Sjukhuset, Gothenburg (21). The average procedure time for all radiographic examination is currently seventeen minutes (21). In comparison the ultrasonography

examination takes about five to ten minutes depending on degree of difficulty. It can also be done immediately after the physical examination when the patient is still in the examination room. Therefore ultrasonography could theoretically decrease the lead times in the emergency department and improve the flow of patients substantially. However, with this procedure the consultations are expected to be slightly prolonged.

Secondly, using fewer radiographs in favor of ultrasonography would most certainly decrease the costs for fracture diagnostics of the distal radius. A single radiographic examination of the wrist is not very expensive; 737 SEK. The big amounts of wrists examined every year though are causing high total costs. In the present Emergency Department, Sahlgrenska University Hospital, Drottning Silvias Barnsjukhus, Östra Sjukhuset, Gothenburg the total cost for primary radiographs of the wrist was to just above 700 000 SEK for the first half of 2014 (22). Not taking variation over the year in count one could expect the yearly cost to reach a total of about 1 400 000 SEK. These costs are only for the radiographs, personnel time and salary are not taken in count. The price of a portable ultrasonography apparatus like the one used in our study costs about 250 000 SEK according to our contact at SECMA AB (23). The lifetime of an ultrasonography apparatus of this kind or how often it needs reparation is not known. In addition to the ultrasonography apparatus transmission gel is needed to perform examinations. This gel normally costs about 10 SEK per 100 ml, which is enough for approximately ten to fifteen examinations. Taken in calculation that there are approximately 1 900 primary radiographs of the wrist every year in the emergency department of Sahlgrenska University Hospital, Drottning Silvias Barnsjukhus, Östra Sjukhuset, Gothenburg the cost for all these patient being examined by ultrasonography instead would lead to a total of 1 200 to 1 900 SEK per year for transmission gel.

Also, fewer radiographs would lead to fewer children exposed to radiation in this group of injuries. A single wrist examination involves very little radiation and numerous radiographic examinations of the wrist would probably be needed to increase the risk of getting cancer. However, even if there is a small risk of developing cancer and no vulnerable organs are present in the area of the wrist, there is still a risk. In addition children are more susceptible to radiation and have a longer life expectancy which are two reasons why the risk of developing cancer is bigger in children than adults (24).

Another aspect is the quality of the images. When a patient, and especially a child, is in pain it can be difficult in several ways to achieve sufficiently good radiographs. The patient can (due to pain) be unable to pronate or supinate the hand and therefore have difficulties placing the wrist in the exact position. This can lead to images that are slightly rotated and therefore difficult to assess. In the worst case scenario the radiographs are so difficult to assess that new radiographs are needed. The physician needs to assess the images in order to determine whether they are of sufficient quality or not. The inability of a child to sit still also makes good radiographs more of a challenge. That the target is completely still is of great importance to get assessable images. Not being able to sit still due to pain may also be a problem when examining with ultrasonography, but the possibilities to calm the child through sitting on the parents' knee are bigger. Also the position of the arm is not crucial to the quality of the images when examining with ultrasonography.

Last but not least it is important that the child can feel safe and secure. That is easier to maintain if the child meets fewer health care workers. Being able to use the ultrasonography technique for examination already in the emergency department could save the child from

visiting the radiology department. The effect of this could be that the child only meets one physician and two or three nurses instead of possibly five nurses and two physicians.

AIM

The project aims to investigate if point-of-care ultrasonography, performed by ultrasonography novice physicians, can be used to detect fractures in the distal radius. The hypothesis is that ultrasonography, in the hands of inexperienced orthopedists and assistant physicians, can triage all patients into three groups depending on expected treatment and follow-up.

Moreover the project aims to discuss whether using ultrasonography can be more timesaving and economical or not. The discussion will also include a paragraph on how the results in this project could affect the total radiation dose given to children, what that could imply and what future research projects could focus on.

ETHICS

This study together with the research work at the Emergency Department, Sahlgrenska University Hospital, Drottning Silvias Barnsjukhus, Östra Sjukhuset, Gothenburg has completed its application for conducting the study in accordance with the prevailing regulations from the Etikprövningsnämnden (EPN), Gothenburg (25). The approval indicates that the WMA Declaration of Helsinki and Human Rights according to The United Nations were taken in account. Permission was granted 2015-02-09, Dnr 956-14 (see “EPN permission” appendix No. 1).

Information, informed consent and confidentiality

Patients fitting the criterion for inclusion but not the criterion for exclusion (see “Study population” page 22) arrived to the emergency department and met someone from the

research group initially. The researcher presented oral information about the study together with written information in both a normal and an easy read version. If the patients and their parents approved participation in the study they signed a form of consent that was later kept with the confidential materials of the study. Routines for storing patient related materials are described below (see “Data storing” page 27).

Ethical considerations

In this section the project is treated through the Medical Principles of Ethics. Patients were well informed that they could quit participation at any time without it affecting the examination and their treatment; they would still get the same treatment as similarly injured patients that were not in the study. Patients also had the ability right from the start to deny participation in the study. The study were not meant to benefit the individual patient in the research situation, radiographs were the gold standard and determined the treatment. However the patient got an extra examination of the arm and could see for herself if, and in that case where the injury was. This may have benefit the patient through better alternatives for the physician to explain in the examination situation what had happened. The examination was non-invasive and involved no radiation or contrast medium that need to be swallowed or injected. For many patients the ultrasonography examination was performed while waiting for the radiographic examination. Normally when a patient attend the medical services with this type of injury the great majority are examined with radiographs even though exceptions can be made theoretically. In this study all patients underwent radiographic examination as well. However one can say that there was not completely identical treatment between the study population and those not included in the study since the study population, in addition to the radiographs, got another examination with ultrasonography.

MATERIALS AND METHODS

Study population

To reach the desired level of evidence based on pre-study power analysis of the injuries studied a study group of 130 patients was considered a minimum. The sample size was depending on 80% power and $p < 0.05$ together with normal distribution, estimating that ultrasonography would find 75% of the fractures. The patients were seeking medical care at the Emergency Department, Sahlgrenska University Hospital, Drottning Silvias Barnsjukhus, Östra Sjukhuset, Gothenburg. Patients were included from the end of February 2015 to the end of May 2015.

Criterion for inclusion

Patients were included if they were of age from 3 to 16 years old and had been exposed to a any trauma resulting in pain or discomfort in any or both distal forearms or wrists during the last three days.

Criterion for exclusion

Patients were excluded if they did not meet the criterion for inclusion or if they displayed an open fracture which could explain the pain or discomfort. Patients were also excluded if the pain or discomfort originated from the elbow, proximal forearm or diaphysis of the radius. Patients were excluded if the pain originated from the hand or fingers as well as if injury on the scaphoid bone was more likely. Furthermore patients were excluded if they and/or their parents did not want to take part in the study as well as if they and/or their parents for any reason were unable to understand the given information. If the patient had impaired circulation to the limb or unstable vital parameters, he or she was not included in the study.

Patients that had already met a physician and had a radiographic examination in the Radiology Department, Sahlgrenska University Hospital, Drottning Silvias Barnsjukhus, Östra Sjukhuset, Gothenburg or elsewhere were excluded if any findings from the radiographs were presented in the referral, otherwise the patient was included.

Physicians conducting the examination

Six physicians (also referred to as study physicians)(orthopedists and assistant physicians of the Emergency Department, Sahlgrenska University Hospital, Drottning Silvias Barnsjukhus, Östra Sjukhuset, Gothenburg) with no previous experience in musculoskeletal ultrasonography underwent the standardized education. The two standardized education lasted for one and a half hours. The education included an oral presentation of the project together with cases collected at the emergency department, with the actual ultrasonography apparatus. The physicians learned how to include and exclude patients according to the criterion for inclusion and exclusion (see “Study population” page22). In addition the physicians theoretically learned the exact way of conducting the physical and the ultrasonography examinations (see “Data extraction” page 24). The last part of the standardized education consisted of practical training. The physicians tried out the ultrasonography apparatus and learned to maneuver the transducer correctly to get the best pictures. All study physicians completed a training session on a patient presenting with a distal radius fracture in the emergency department before they started to include patients in the study. A radiologist connected to the research work, took part in the standardized education to observe and assist the research group in teaching ultrasonography but the information and training was identical.

Ultrasonography apparatus

The apparatus used was a FUJIFILM SonoSite, inc: Edge® (26). The probe used was a linear FUJIFILM SonoSite, inc: HFL50X, 15-6MHz connected to the ultrasonography apparatus (27). The ultrasonography apparatus had an electric cord but also ran on an internal battery

which could be charged using the electric cord (see "Figure 5"). Two different brands of transmission gel were used throughout the project. PARKER LABORATORIES, INC: Aquasonic® 100, Ultrasound transmission gel (28) was used initially. Later on HANDELSHUSET VIRODERM AB: Lectro Derm 1 (29), Ultrasound transmission gel was used. The change in brand was simply because the Emergency Department and the Radiology Department, Sahlgrenska University Hospital, Drottning Silvias Barnsjukhus, Östra Sjukhuset, Gothenburg used another brand than the one that came with the ultrasonography. The change in brand was expected not to influence the results in any way. Data collection



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Figure 5, The ultrasonography apparatus with components.

Examination algorithm

The examination was divided into three parts where all study participants underwent all examinations. The order was by default clinical, ultrasonography examination and radiographic examination. However, sometimes the triage nurses had already referred the patient to radiographic examination to speed up the work at the emergency department. In cases with existing radiographs, the study physicians were allowed to carry out the clinical and ultrasonography examinations as long as they had not yet seen the radiographs or read the radiologist's report. Patients are never informed of the radiographic findings in the radiology department.

Clinical examination

The clinical examination was in two parts, history taking and physical examination. The history taking aimed to find out what caused the injury, where the patient located the major part of the pain and if the patient had pain elsewhere on the body as an effect of the trauma. After that the physical examination began starting with inspection of the forearm and wrist to find any deformity or swelling. Next the physician palpated the pain free parts of the arm including brachium, elbow (paying special attention to the epicondyles, radial head and olecranon) and the hand (fingers, metacarpal bones and carpal bones), it was also important to determine whether there might be an injury on the scaphoid bone (done through axial compression of the thumb and palpation dorsally and palmar of the scaphoid bone). There should be no pain in the examined body parts although pain from the wrist during examination was accepted. Then the physician investigated if any pain was present during flexion and extension of the elbow or pronation and supination of the wrist. Like before pain from the wrist during examination was accepted. The physician should verify if the pain was located to the distal radius only, injuries to the diaphysis or more proximal were not to be included in the study. Last the distal status should be verified not to have any defects. This was done through sensory testing of the ulnaris, radialis and medianus nerves, motor testing of the strength in the hand and fingers, together with testing of the capillary functions by pinching the fingertips and observing how long time the color needed to return.

Ultrasonography examination

The bag containing the ultrasonography apparatus was located in a locked room which all study physicians had access to in the orthopedists' department. When one of the researchers was present at the emergency department the ultrasonography bag was located to the orthopedists' office at the emergency department. Before the examination the examiner started the apparatus and prepared it for examination by creating a new patient form and

filling it in with the right information (initials of the patient, the patient's date of birth and the initials of the examiner) in the right places. The examination began with the application of a sufficient amount of transmission gel in the area of the distal radius dorsally. After that the transducer was placed along the radius on its dorsal side (sagittal). To ensure that the images were as uniform as they could the little bump on the transducer was located as distal as possible. First the physis was identified together with the epiphysis and the wrist. Thereafter the transducer was slid from the ulnar to the radial side of the radius slowly and the examiner looked for deformity, cortical fractures or other abnormal findings. This procedure was then repeated on the ventral side of the radius. The examiner had the opportunity to compare any findings with the patient's sound arm to pay attention to possible anatomical variations. The study physician also examined the most painful spot specifically. He or she had the opportunity to turn the transducer to transversally direction to visualize any findings better. In addition representative ultrasonography images were saved to the internal drive of the ultrasonography apparatus if the study physician found that necessary. Even videos could be recorded to better visualize the findings. After examination the study physician formed opinions of the ultrasonography and then filled in the second form concerning the skeletal status. The four possible outcomes on the ultrasonography examination were based on what the study physician considered was the appropriate treatment (see "Table 5"). If the study physician deemed that there was no fracture and no treatment was needed he or she marked the alternative "no fracture". If the study physician thought there was a fracture that could be treated through a cast only that is taken off at home with no control radiograph or revisit he or she marked the alternative "infracture/greenstick fracture". If the study physician thought there was a fracture that needed reposition, surgery, control radiographs or revisits in addition to the cast he or she marked the alternative "total fracture". The fourth alternative "uncertain

findings” was used to elucidate how often the study physicians were not sure enough to make a decision on the skeletal status. The examination took between five to ten minutes.

Radiographic examination

The radiographic examinations were performed by the Radiology Department, Sahlgrenska University Hospital, Drottning Silvias Barnsjukhus, Barnröntgen, Östra Sjukhuset, Gothenburg. Radiographs were created of the wrist (including the distal half of the radius and ulna together with carpal and metacarpal bones of the hand). Two projections were used (the frontal view and the side view), normally two radiographs were created, but sometimes there were difficulties in getting a good focus why three radiographs sometimes was created. The physician conducting the ultrasonography examination formed opinions of the radiographs and then filled in the third examination form concerning the skeletal status. The four possible outcomes were the same as in the ultrasonography examination (see “Ultrasonography examination” page 25). Then were, at the earliest, the physician allowed to read the radiologist’s report and take decisions about the treatment. As the design of the method aimed to simulate the conditions at the Emergency Department, Sahlgrenska University Hospital, Drottning Silvias Barnsjukhus, Barnröntgen, Östra Sjukhuset, Gothenburg as far as possible, the ultrasonography assessments were compared with the study physicians’ radiograph assessments. This was because physicians working in the emergency department normally decide the treatment based on their assessment of the radiographs (see “Standard procedure for diagnosis and treatment in the emergency department” page 12).

Data storing

Storing of data consisted of two parts. There were the three forms filled in by the study physician and there was the electronic storing of images from the ultrasonography and the radiographs. During the ultrasonography examination (see “Ultrasonography examination” page 25) the examiner saved images that were later transferred to a digital database mentioned

later in this section. The radiographs were saved unidentifiable from Remix (the application for radiograph management in Västra Götalandsregionen) to the digital database.

The research binder was always placed in the orthopedists' office at the emergency department. In the binder were a series of plastic folders which contained three envelopes each marked with a, for the plastic folder, unique number. The plastic folder also contained the form of consent and written information about the research work in both a normal and an easy read version for children. Last there were three forms for the physician to fill in (see "Study forms" appendix No. 2), all marked with the same number as the envelopes. The first form was an identification form where the physicians put a patient label and wrote down the date of examination. The second form treated the clinical and ultrasonography examination. Here the study physician wrote down her name and answered seven questions about; deformity, location of the pain, pain during movement and need for radiographs. In the second form the physician also marked the best fitting alternative of the skeletal status from their ultrasonography examination and wrote down any comment on the clinical and ultrasonography examination. In the third form the physician formed an opinion on the skeletal status by looking at the radiographs without reading the radiologist's report and then marked the best fitting alternative in the form. There was also a possibility of writing down comments on the radiographic examination. When a form was filled in the physician folded it and put it in one of the envelopes which was finally sealed and put in the plastic folder. All patient related materials were initially stored coded in sealed envelopes in the orthopedists' office in the emergency department. After opening of the envelopes and insertion in the digital database the confidential material was stored in a binder that was locked up in an orthopedist's personal office room. Research data is stored for ten years before destruction. The digital database used was FileMaker Pro 13 Advanced on a local drive (30).

Special cases

Data storing in special cases are shown in "Table 7".

Table 7, Presentation on how special cases are handled when including and saving images and data.

Special cases	Action
Patient with two suspected distal radius fractures (one on each arm)	Patients were included as two separate patients, one for each arm. The study physician conducted the exact same procedure as for a normal patient but he or she conducted the procedure twice. Two files were created in the ultrasonography apparatus and they were named with the patients initial followed by "1" and "2" respectively. The physician also made sure to mark in the paper forms which arm (left or right) belonged to the specific patient-ID. This was so that later control and comparison with radiographs could be done.
Patient with secret identity	Patients were treated the same way as any normal patient except the study physician did not fill in the patient's initials. Instead the physician filled in "SI" (for secret identity) followed by a number from one and up (in case there were more than one secret identity one day), resetting every day.

Treatment

The treatments for the patients' conditions were not subject to research in this study, also no follow up was held. The patients got their treatment in the exact same way as patients not participating in the study. The treatments followed the guidelines (see "Standard procedure for diagnosis and treatment in the emergency department" page 12).

Statistic analysis

Generation of tables was done using Microsoft® Office Excel® 2007, version 12.0.6718.5000 (© 2008 Microsoft Corporation) for Windows. The statistic analysis was carried through using IBM® SPSS Statistics, version 22.0.0 (© 2013 IBM Corporation). The distribution of cases in relation to age and sex was calculated. A One-sample T-test was performed to measure the overall concordance between ultrasonography and radiograph assessment. A 95% two-sided confidence interval was used for presentation (95% CI). A cross tabulation was used to measure and present the inter-rater agreement between ultrasonography and radiographs. Cohen's Kappa was calculated to analyze the level of agreement, using a scale of

interpretation according to Landis, J. R. et al (31). A 95% two-sided confidence interval was used for presentation (95% CI). The 95% CI was calculated through the formula: CI = value of Kappa +/- 1,96 x standard error of value of Kappa. Cohen's Kappa is said to be more accurate since it takes in account agreement occurring by chance. The four outcomes used in the ultrasonography and radiograph assessment were merged into two groups ("No fracture" became "Would not have needed radiographs" and the three other outcomes were considered possible fractures and became "Would have needed radiographs") to be able to calculate sensitivity and specificity (95% CI) and compare our study with previous studies.

RESULTS

Three patients were excluded, one case due to pain over the diaphysis and two cases due to suspected fracture on the scaphoid bone. A total of sixty-nine patients were included in the study. Two patients had suspected fractures on both forearms and were therefore counted as four (two times two) patients in the total compilation and one patient had a secret identity (see "Table 7"). There were thirty-four males and thirty-five females."Table 8" and "Table 9" shows the distribution in sex and age within the study population.

Table 8, The distribution of cases included in the study: Column two (number) and column three to seven (years).

Sex	N
Female	35
Male	34
Total	69

Table 9, The distribution of ages in the study: Column one (years), column two (number) and column three (percentage of total).

Age distribution	N	% of Total N
5	2	2,9%
6	4	5,8%
7	7	10,1%
8	6	8,7%
9	7	10,1%
10	6	8,7%
11	6	8,7%
12	14	20,3%
13	8	11,6%
14	7	10,1%
15	2	2,9%
Total	69	100,0%

The One-sample T-test calculations show the overall concordance between the ultrasonography and the radiograph assessments (see "Table 10"). The assessments were identical in 84.1% of the cases (95% CI, 75%-93%).

Table 10, The concordance between the study physician’s ultrasonography and radiograph assessment.

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Concordance between ultrasonography and radiographs	18.935	68	0.000	0.841	0.75	0.93

The ultrasonography examinations took between five to ten minutes to perform. According to "Table 11" there were forty-nine fractures, sixteen non-fractures and four uncertain findings seen on the radiographs. The study physicians overestimated the number of fractures by two and found all "Infraction/Greenstick fracture" in ultrasonography assessment. No fracture was

missed but five of fourteen “Total fractures or unacceptable deformation” was incorrectly classified as “Infraction/Greenstick fracture”.

Table 11, A comparison between the assessments in of the ultrasonography (rows) and the radiographs (columns). To the right and at the bottom there are the total numbers of outcomes with percentage respectively.

Ultrasonography vs. Radiograph, Crosstabulation

		Radiograph assessment				Total
		No fracture	Infraction/Greenstick fracture	Total fracture or unacceptable deformation	Uncertain finding	
Ultrasonography assessment	No fracture	12	0	0	1	13 (18.8%)
	Infraction/Greenstick fracture	1	35	5	1	42 (60.9%)
	Total fracture or unacceptable deformation	0	0	9	0	9 (13.0%)
	Uncertain finding	3	0	0	2	5 (7.2%)
Total		16 (23.2%)	35 (50.7%)	14 (20.3%)	4 (5.8%)	69 (100%)

The value of Cohen’s Kappa was 0.742 (95% CI 0.61-0.88) which correlate to the higher layers of “Substantial agreement” in the Kappa interpretation scale (see scale “Kappa Interpretation” below)(31).

Kappa Interpretation.

- < 0 Poor agreement
- 0.0 – 0.20 Slight agreement
- 0.21 – 0.40 Fair agreement
- 0.41 – 0.60 Moderate agreement
- 0.61 – 0.80 Substantial agreement**
- 0.81 – 1.00 Almost perfect agreement

Table 12, The measurement of Cohen’s Kappa based on the “Ultrasonography vs. Radiograph crosstabulation”.

Cohen's Kappa						
	Value	Asymp. Std. Error ^a	Approx. T ^b	Approx. Sig.	95% Confidence Interval of the Difference	
					Lower	Upper
Measure of Kappa Agreement	0.742	0.068	9.572	0.000	0.61	0.88
N of Valid Cases	69					

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

When the four outcomes of the study were merged into two groups (“Would not have needed radiographs” and “Would have needed radiographs”) to be able to compare with previous studies, the sensitivity and specificity were calculated. The sensitivity for being able to send the patient to radiographic examination was calculated to 98.1% (95% CI, 90.1%-99.7%) and the specificity was calculated to 75.0% (95% CI, 50.5%-89.8%).

On page 34 is a collection of images presenting the characteristics of the outcomes used in the examinations (see “Figure 6”). There is an intact distal radius on a dorsal (a) and volar (b) ultrasonography view together with a frontal (c) and a side (d) radiograph. There is a distal radius infraction on a dorsal (e) and volar (f) ultrasonography view together with a frontal (g) and a side (h) radiograph. There is a complete distal radius fracture on a dorsal (i) and volar (j) ultrasonography view together with a frontal (k) and a side (l) radiograph.

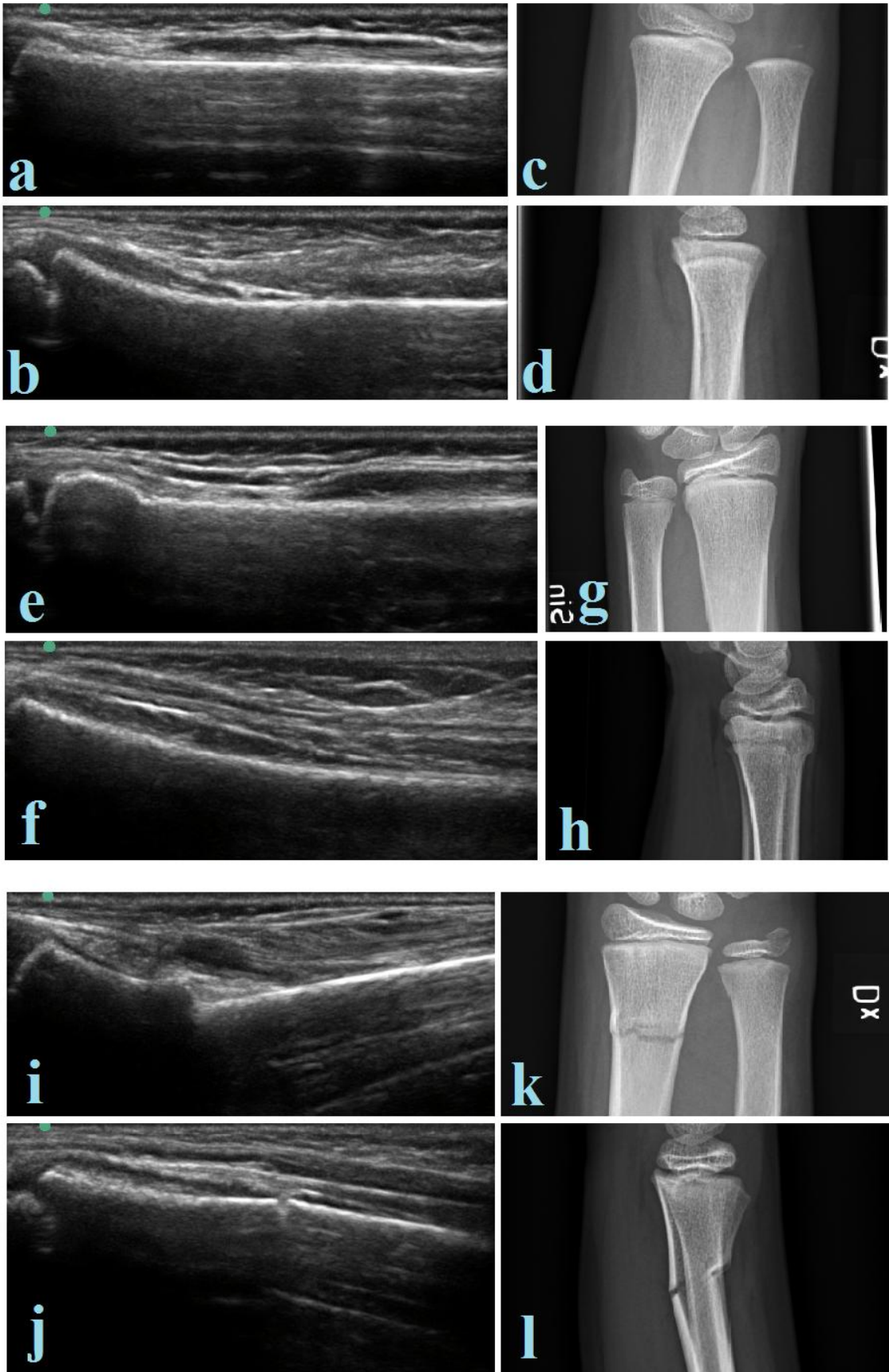


Figure 6, Three skeletal statuses of the distal radius: Ultrasonography (left column) and radiograph (right column). Letters are described in the text.

DISCUSSION

The relatively low number of patients included (sixty-nine compared to one-hundred and thirty wanted) was due to a late start. The research group had trouble finding an ultrasonography apparatus that could be used in the study. Therefore the inclusion started February 20, 2015 instead of during autumn 2014 as originally planned. The study will however extend over the summer 2015 to reach the desired number of inclusions making this study a preliminary report over the current results. The results are not to be trusted fully since we never reached one-hundred and thirty inclusions which were needed for statistical significance. Numbers, trends, assumptions and conclusions however, indicate how the full scale study will turn out.

In the study we wanted to investigate if ultrasonography could be performed without previous experience if the algorithm was short, distinct and easy to follow. Six orthopedists or assistant physicians with no experience in musculoskeletal ultrasonography were involved. They have included between four and thirty-two patients each and following was noticed (note that the bulleted list below is based on observations and was not specifically measured during the project):

- The learning curve appears to be very steep and fast reaches a plateau. All study physicians had some trouble finding the right ways to perform and assess the ultrasonography examination during their first two patients but very quickly learned to handle the apparatus confidently. Hertzberg, B. S. et al concluded that as many as two-hundred ultrasonography examinations has to be done before a physician can be said to have a acceptable level of competence in ultrasonography (32). The reason why we had the physicians learning faster is probably that; the radius is easily viewed due to its close relation to the skin, the study physicians had only a few tasks to assess and

when a sharp ultrasonography image is achieved it looks very similar to a corresponding radiograph (which all study physicians were familiar to).

- The frequency of misjudgments between ultrasonography and radiographs were relatively dependent of how many patients the study physician had examined. Almost half of the misjudgments were done on the study physicians' first two patients but the rest seemed to have no relation to the number of patients examined. This suggest that ultrasonography, like the majority of medical examinations, needs a little practice before it can be performed securely.
- The examination duration seemed not, or very remotely, connected to the number of patients a study physician had examined. The majority of the examinations took between five to ten minutes and the time seemed to be more connected to how discrete the fracture was than how experienced the physician was.

The number of identical assessments on the ultrasonographies compared to radiographs were fifty-eight out of sixty-nine (see "Table 11") which correspond to 84.1% (see "Table 10") and a Cohen's Kappa of 0.742 (substantial agreement)(see "Table 12"). This number may seem relatively low compared with previous studies (10-13, 15-20) but it is important to keep in mind that this study design featured four possible outcomes instead of the binary "fracture" or "no fracture". However, when transforming our results to fit the binary "fracture" or "no fracture", three of the outcomes in our study ("Infraction/greenstick", "Total fracture or unacceptable deformity" and "uncertain finding") were merged into one group called "Would have needed radiographs" to oppose the group "Would not have needed radiographs" made up by our outcome "No fracture". This gave our study a sensitivity of 98.1% and a specificity of 75%. The sensitivity is similar to previous studies but the specificity differs which can be an effect of an insufficient number of inclusions in the study (lower than calculated in the power

estimate). Another possible explanation of the relatively low specificity could be that in our study design the physicians had the opportunity to choose “Uncertain finding” instead of only “Fracture” or “No fracture”. This could lead to a scenario where radiographically verified non-fractures were classified as “Uncertain finding” only because the study physicians were not confident enough in assessing the ultrasonography to say that there was no fracture, even if they could not find any during the ultrasonography examination.

On the other hand, if these numbers are to trust, thirteen patients (18.8%) would not have needed radiographic examinations in the first place since ultrasonography had ruled out fracture. When analyzing the individual cases we found that no radiograph verified fractures were missed on the ultrasonography but one case of “Uncertain finding” were classified as “No fracture” after ultrasonography. However, in this specific case the study physician could not find any fracture on the radiograph but in the same time could not rule it out.

Eleven out of sixty-nine misjudgments were done (see “Table 11”). Five cases were more severe in the radiograph assessment than in the ultrasonography assessment. These misjudgments were done by different physicians and no pattern was detectable. Since it is of interest to be able to differ between “Infraction/Greenstick fracture” and “Total fracture or unacceptable deformity” those five cases were inspected separately. One case unfortunately did not have saved ultrasonography images. One case clearly displays a “Total fracture or unacceptable deformity” on the saved ultrasonography images but for some reason it was missed. The other three cases all had in common that they were dorsally bent fractures with relatively little deformity and displacement. The lack of displacement, especially in the volar cortex breakage led to difficulties in getting a sufficiently sharp ultrasonography image to see the fracture.

Five cases of radiograph verified “No fracture” or “Uncertain finding” were classified as “Infraction/Greenstick fracture” or “Uncertain finding” on ultrasonography assessment. One explanation to this relatively high number of overestimations could be that the study physicians tended to also take the physical examination in account. This means that even though the study physicians could not see a fracture on the ultrasonography examination, a clear and distinct suspicion of a fracture from the physical examination sometimes led to the overestimation. One would argue that the same effect should be seen when assessing radiographs, that the findings from the physical examination would affect the assessment to overestimation of the number of fractures. A possible counterargument is that the study physicians felt more comfortable in assessing radiographs and therefore trust their findings to a greater extent.

In the future it is possible that ultrasonography could be incorporated in more than diagnostics or triage of distal radius fractures. Next step would be to investigate what role ultrasonography could have in reposition and treatment of distal radius fractures. Also other “skin near bones” could benefit from an ultrasonography examination for the same reasons as distal radius. For instance the clavicle would in theory be easy to visualize and some studies have shown that other long bones and some other bones are relatively easy to examine with an ultrasonography apparatus, at least if you are trained in ultrasonography (10, 13, 17, 20).

Having a portable ultrasonography apparatus in the emergency department could also benefit other professions such as the field of medicine or surgery. Two common reasons for attending children’s medical services in the field of surgery are stomach pain and foreign body. As concerns the foreign body a portable ultrasound could probably help the situation in the

emergency department by assisting in finding and removing the foreign body (33). Even surgeons with little ultrasonography experience could easily perform an examination and save the patient from waiting several hours at the radiology department. Stomach pain is also often examined with ultrasonography due to suspicion of appendicitis. However, this procedure requires some training but in the future a portable ultrasonography apparatus could make an important option to reduce lead times in the emergency department. Also acute situations are of interest and the portable ultrasonography could maybe be used to detect pneumothorax and free blood in the abdomen and thorax (a procedure called FAST).

Methodological considerations

The hypothesis and aim were adequate. Also the group of study physicians with no former ultrasonography experience was adequate since they represented the orthopedic personnel at the Emergency Department well. That together with the short standardized introduction served its purpose well in simulating that anyone, independent of former ultrasonography experience, could perform the examinations and assessments. Also the storing of data, recording of images and filling of study forms were arranged adequately and were easily understandable for the study physicians involved. However, learning a new examination technique requires practice (compare using stethoscope or assessing echocardiography). In this study design we had the study physicians including patients after very little practice to simulate inexperience. A big portion of misjudgments occurred during the study physicians first two inclusions before they were confident enough to use the ultrasonography apparatus properly. After that misjudgments occurred more rarely. The research question also focused on whether the study physicians could differ between the various types of fractures. Here is room for improvement in the examination algorithm since five of fourteen “Total fracture or unacceptable deformity” were incorrectly assessed to be “Infraction/Greenstick fracture”. One way avoid the problem is to examine the contra lateral cortex extra carefully in those cases

where a breakage is found in dorsal or volar cortex. Using palpation simultaneously to ultrasonography examination more frequently is another way to easier diagnose “Total fracture or unacceptable deformity”. A third improvement of the study design would have been better control beforehand on how the study physicians assess radiographs since it was obvious during the study that there was individual variation in what the study physicians counted as fractures and what did not. Bigger attention to radiograph assessment could have improved the results.

CONCLUSION AND IMPLICATIONS

Ultrasonography in triaging distal radius fractures has a big potential; a tool to roughly decide which patients need to undergo radiographic examination and which patients do not.

Ultrasonography-novice physicians managed to find all radiograph verified distal radius fractures during ultrasonography examination. However, the algorithm was not accurate enough to separate the less severe fractures (needing only a cast as treatment) from the more severe (often needing more than a cast, such as control radiographs, reposition or surgery).

Further research is needed. It should focus on how to improve the examination algorithm so that the study physicians can more easily, precisely and with confidence differ between incomplete and complete fractures. This research could possibly lead to an inclusion of ultrasonography in the diagnostic toolbox for distal radius fractures in the future.

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POPULÄRVETENSKAPLIG SAMMANFATTNING

Handledsfrakturet hos barn: Kan ultraljud minska behovet av röntgen?

Frakturet är överrepresenterade på barnakuten och handledsskador är särskilt vanliga. Idag undersöks alla dessa patienters handleder med röntgen som är både kostsam och tidsineffektiv samt utsätter patienterna för strålning. Denna studie visar att ultraljud kan minska behovet av röntgen vid diagnostik av handledsfrakturet hos barn i framtiden. Dock behövs tydligare undersökningskriterier för att på ett tryggt sätt skilja på de olika frakturtyperna.

Ultraljud har kritiserats för att vara svårtolkat utan tidigare utbildning i ultraljudstolkning. Denna studie visade att detta inte är helt sant genom att låta sex ortopedier och underläkare som aldrig tidigare jobbat eller utbildat sig med ultraljud ingå i studien. Dessa läkare fick en kort introduktion till studien och instruktioner hur det skulle genomföra ultraljudsundersökningarna. Läkarna bedömde ultraljudsfyndet identiskt med röntgenfyndet i 58 av 69 fall (84%) och inga frakturet missades även om 5 av 49 frakturet (10%) felklassificerades. Alla felklassificeringar var underskattningar av frakturens allvarlighetsgrad.

De läkare som gjorde undersökningarna i studien undersökte först patienterna fysiskt enligt gällande rutiner. Därefter gjordes en ultraljudsundersökning enligt den metod som framtagits av forskarlaget. Det var viktigt att läkaren, innan ultraljudsundersökningen, inte tog del av redan tagna röntgenbilder och bedömningar. Därefter bedömde läkaren själv röntgenbilderna. Slutligen jämfördes hur läkarna hade bedömt ultraljudsundersökningen med hur de hade bedömt röntgenbilderna.

Denna studie visar att ultraljud utfört direkt på akutrummet har stor potential att kunna reducera såväl strålningen mot denna patientgrupp samt akutmottagningens kostnader och väntetider. Ett akutbesök skulle kunna kortas så mycket som en timme med rätt förutsättningar. Den ekonomiska vinsten för vårdinrättningen är svårare att kalkylera, men en årlig kostnad på ungefär 1,4 miljoner kronor för röntgenundersökningar (2014) kan jämföras med en engångskostnad på ungefär 250 000 kronor för ultraljudsapparaten.

Som synes skulle denna studie kunna få stor betydelse för den enskilde patienten och samhället i stort, inte minst på grund av flödet på akuten och den ekonomiska vinsten. Att kraftigt kunna reducera antalet röntgenundersökningar för en av de största patientgrupperna på barnakuten skulle också leda till att röntgenundersökningar blir tillgängliga för andra grupper snabbare än idag. Med den ekonomiska vinsten finns även ökat utrymme för satsningar inom andra områden i vården.

Denna studie öppnar flera dörrar för framtida forskning. Dels kan det vara av intresse att se hur ultraljud kan ha betydelse vid behandling av den här typen av frakturer. Idag tillrättaläggs många frakturer med hjälp av röntgen, men några tidigare studier antyder att ultraljud ska kunna vara ett användbart substitut. Dessutom kan andra professioner så som barnkirurgin dra nytta av att ha tillgång till en ultraljudsapparat på akutmottagningen

Nu efterfrågas forskning på ett större antal patienter för att kunna analysera resultaten noggrannare och dra tydliga slutsatser. Det är av största intresse att fundera på hur undersökningsmetoden kan förändras för att inga frakturer ska missas eller feltolkas.

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APPENDICES

Appendix No. 1
EPN permission

Regionala etikprövningsnämnden i Göteborg

Projektansvarig:
Henrik Hedelin
SU/Drottning Silvias barn- och ungdomssjukhus
Rondvägen 10
416 75 Göteborg

Dnr:
956-14

Exp. 2015-02-11

ANKOM
2015-02-16

Ortopedi SU/Östra

Forskningshuvudman: Västra Götalandsregionen, Sahlgrenska universitetssjukhuset,
Mölndal, 431 80 Göteborg

Närvarande beslutande:

Göran Bodin, *ordförande*
Lennart Andrén, *vetenskaplig sekreterare*

Ledamöter med vetenskaplig kompetens:

Christina Bergh (*deltog ej i 811-14 p g a jäv*)
Jane Carlsson
Ingrid Emanuelson
Gunnar Göthberg
Margareta Kreuter
Margareta Hellgren Wångdal
Thord Rosén
Frode Slinde
Hans Ågren (*deltog ej i 029-15, 030-15, 033-15, 034-15, 038-15 och 039-15*)

Ledamöter som företräder allmänna intressen

Bengt Andersson
Ulla Buhr
Berit Frändås
Heléna Okomdal Holmgren
Karin Ström

Projekttitel: Akut ultraljudsdiagnostik av skadade underarmar hos barn - kan ortopederna göra en första bedömning?

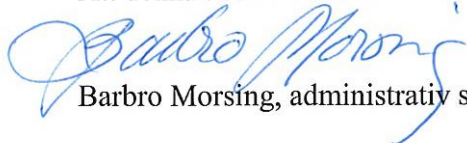
Beslutsprotokoll från sammanträde med Regionala etikprövningsnämnden i Göteborg, Medicinska avdelningen (M 1), den 9 februari 2015

Föredragande: Ingrid Emanuelson

Godkännes

Nämnden beslutar godkänna studien.

Att denna avskrift i transumt överensstämmer med originalet intygar



Barbro Morsing, administrativ sekreterare

Appendix No. 2
Study forms

Identifieringsblad

Patient studie-ID:

Patient-ID:
(klisterlapp)

Undersökningsdatum:

Undersökningsblad

Patient studie-ID:

Undersökande läkare:

Klinisk undersökning

Angulering på utanpåskriften:	JA <input type="checkbox"/>	NEJ <input type="checkbox"/>
Palpationsöm över humerusepikondylerna/caput radii:	JA <input type="checkbox"/>	NEJ <input type="checkbox"/>
Smärtmaximum över karpalben eller scaphoideum:	JA <input type="checkbox"/>	NEJ <input type="checkbox"/>
Smärta vid rörelse i armbågsled:	JA <input type="checkbox"/>	NEJ <input type="checkbox"/>
Smärta diafysärt/proximalt vid pronation/supination:	JA <input type="checkbox"/>	NEJ <input type="checkbox"/>
Tydligt lokaliserad smärta till enbart distala radius:	JA <input type="checkbox"/>	NEJ <input type="checkbox"/>
Skulle du ha valt att röntga endast handleden:	JA <input type="checkbox"/>	NEJ <input type="checkbox"/>

Ultraljudsundersökning

Ultraljudsutlåtande (enbart distala radius):

INGEN FRAKTUR

INFRAKTION/GREENSTICKFRAKTUR

GENOMGÅENDE FRAKTUR
alt. STOR ANGULERING

OSÄKERT FYND

Kommentar till ultraljudsfynd (beskriv med egna ord ett annorlunda fynd, kommentarer till undersökningsproceduren eller innebörden av "osäkert fynd" i detta fall):

Röntgenblad

Patient studie-ID:

Röntgenutlåtande (enbart distala radius):

INGEN FRAKTUR

INFRAKTION/GREENSTICKFRAKTUR

GENOMGÅENDE FRAKTUR
alt. STOR ANGULERING

OSÄKERT FYND

Kommentar till röntgenfynd (beskriv med egna ord ett annorlunda fynd, kommentarer till undersökningsproceduren eller innebörden av "osäkert fynd" i detta fall):