Explore the Role of Ultrasound in Pediatric Radiology, Focusing on its safety, accuracy, and effectiveness in Diagnosing Various Pediatric Conditions

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Abstract

Background: *An ultrasound of the chest is a noninvasive diagnostic tool used to evaluate the lungs, mediastinum (the chest cavity that houses the heart, aorta, trachea, esophagus, thymus, and lymph nodes), and pleural space (the area between the lungs and the chest wall). Using ultrasound, the internal organs and structures of the chest may be quickly and clearly seen from the outside. It is possible to evaluate heart and lung function using ultrasound. This research explores the perspectives of young patients who had emergency chest surgery and afterwards underwent a series of radiography examinations.* ***Aim:*** *The purpose of this research is to compare the accuracy of bedside chest ultrasonography (CUS) and chest radiography (CXR) in assessing postoperative complications after pediatric heart surgery.* ***Methods:*** *One hundred and forty patients were included in our analysis. IBM's version 25 of the SPSS statistical analysis program was used.* ***Results:*** *Ninety-three CXRs were normal among a total of 140. In 47 chest x-rays, the surgeon saw anything out of the ordinary. Seventy-two of the CUS investigations found nothing out of the ordinary, whereas 68 did. Sixty-nine trials had normal results from both CUS and CXR. Kappa statistics revealed a very high level of agreement, with a Kappa coefficient of K=0.749 (p <0.0001). CUS has a sensitivity of 96.9%, specificity of 84.75%, PPV of 73.4%, and NPV of 98.43%.* ***Conclusion:*** *Due to its excellent specificity, sensitivity, negative and positive predictive values, ultrasonography is deemed safe and useful for diagnosing chest surgery.*

Keywords: Diagnosing, Pediatric, Ultrasound, Radiology, heart surgery

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INTRODUCTION

When it comes to detecting and treating musculoskeletal disorders in children, ultrasound is a go-to imaging modality. Because it does not involve radiation, is painless, and does not need the patient to be separated from their parent, it is well tolerated by youngsters. It doesn't need anesthesia or lengthy hospital stays, is easily accessible in a variety of therapeutic settings, and may be done right at the patient's bedside. A targeted history may be taken thanks to the interaction between the doctor doing the operation and the patient and parent. The process is meant to work in tandem with a physical examination to help rule out potential diagnoses. Multiple imaging sites, including the contralateral side for comparison, and real-time evaluations are available to the physician [1-5]. Injections, aspiration, drainage, and biopsies of musculocutaneous disorders may all be guided by ultrasound [4]. However, poor training of physicians typically impedes efficient usage of ultrasound in clinical treatment [2, 3], since the quality of ultrasound pictures is operator dependent and might be restricted by patient participation.

Developmental dysplasia of the hip, fracture treatment, joint effusions, and other superficial musculoskeletal diseases are common pediatric orthopaedic problems where ultrasonography may be useful in diagnosis and therapy [2]. To better see children's tiny and superficial structures, a high-frequency (10-15 Hz) linear transducer is recommended. Size, shape, and type (cystic vs. solid) of a lesion may all be described. Doppler function may also be used to assess blood flow [1, 2].

Radiologists with training in pediatric radiography specialize in providing diagnostic imaging services to children and adolescents from infancy to age 14.

Medical professionals increasingly rely on radiographic examinations for the assessment and diagnosis of a wide range of disorders. A wide range of imaging techniques (such as X-ray, CT scan, MRI, and US) are used for this purpose; nevertheless, some of these techniques may expose patients to potentially dangerous ionizing radiation. The usage of imaging modalities has increased considerably as a result of the development of new technologies and quick advancements in imaging technology.

Difficulties with pediatric imaging

Acquiring high-quality pictures and the child's confidence and participation are crucial in pediatric radiography. The kids need a highly engaging environment that can quickly grab their attention. The space must be inviting, devoid of distractions, and conducive to rest. Toys, play figures, and cartoons should be put in the room, and the walls should be painted with vivid colors and decorated with paintings and pictures. In order to help calm the child's fears and worries, several experts advise using distraction strategies. Distraction projectors are useful in the x-ray room. All electrical appliances should be used with caution, and it's important to keep the cords tucked away neatly so that people don't trip over them.

The initial contact with a kid or patient is crucial, as it establishes the foundation for a lasting connection and boosts the likelihood of a successful examination going forward. Not many technicians like dealing with patients who are uncooperative; patients who are always on the move provide particular challenges. The ideal candidate would have a genuine interest in and genuine patience for dealing with children as patients. Technologists need to have empathy and compassion for kids of all abilities, including those with developmental delays. Only then can they do their job in a way that leaves the kid smiling and the parents satisfied once the test is over. There are two prerequisites for successful radiographic investigations:

1. The radiographer should be well-versed in the use of radiologic equipment and
2. The radiographer has a positive attitude and approach while working with children.

The transducer used in ultrasound generates ultrasonic waves at an audibly inaudible frequency. Ultrasound involves placing a transducer on the skin and sending sound waves deep inside to examine internal organs and tissues. The sound waves hit the organs, and like an echo, they reflect back to the transducer. A computer takes the data from the reflected waves and converts it into a picture of the organs or tissues under investigation.

The speed at which the sound waves travel is affected by the material they are passing through, with bone tissue being the quickest and air the slowest. The transducer interprets the varying rates at which the sound waves are reflected back to it as representing distinct tissue kinds. To improve sound transmission and facilitate the transducer's movement across the skin, ultrasonic gel is applied to both the transducer and the patient.

Doppler ultrasonography, often known as a duplex examination, is used to see the rate and course of blood circulation inside the chest. The Doppler test uses audible sound waves, which are not present in a regular ultrasound. Due to the absence of radiation and contrast dyes, ultrasound may be used safely at any time during pregnancy.

Particularly when just a little quantity of fluid is present, a chest ultrasonography may be utilized to evaluate whether or not the pleural space or other chest locations have extra fluid. Ultrasound may help distinguish between exudate (found in inflammatory, malignant, or infectious disorders) and transudate (fluid that has seeped from blood or lymph vessels for different causes) if there is excess fluid. It is also helpful for checking out the heart and its valves. An echocardiogram is the term used when this method is used to examine the heart.

Thoracentesis (the piercing of the chest wall for the evacuation of fluids) and biopsies may be done with the use of chest ultrasonography to guide the needle. The diaphragm's mobility may also be evaluated using chest ultrasonography. Evaluation and diagnosis of chest diseases may also use additional diagnostic procedures, such as computed tomography (CT), X-ray, or magnetic resonance imaging (MRI), in addition to, or instead of, chest ultrasonography.

METHODS

The research comprised 140 participants ranging in age from 1 month to 18 years. Both chest X-rays and ultrasounds were performed on the same set of patients and compared. The patient was placed in a semi-recumbent posture for the chest ultrasound. An antero-posterior CXR is acquired using a portable X-ray equipment while the patient is in a semi-recumbent posture. The King Saud Medical City Children's Hospital in Riyadh, Saudi Arabia was the focus of this study.

Sample size calculation

One hundred and forty patients were included in our analysis. IBM's version 25 of the SPSS statistical analysis program was used. A 95% confidence interval and a 5% margin of error were used to determine the required size of the sample.

Inclusion criteria

- One population that benefits from heart and artery surgery is children.

- The range of ages covered is from one month to eighteen years.

Exclusion criteria

- Hematic instability
- Urgent operation
- Refusal to Provide Consent

Participants

Patients hospitalized to the Pediatric Cardiothoracic Intensive Care Unit for post-operative care between May 2022 and June 2023.

Design

To assess the reliability of chest ultrasound as a diagnostic tool, a prospective, cross-sectional observational research was conducted from May 2022 through June 2023 at the Radiology department of the Pediatric Hospital at King Saud Medical City. The youngsters in this research all had symptoms that were consistent with needing cardiac surgery. Values for ultrasound's sensitivity, specificity, negative predictiveness, and positive predictiveness were computed [5].

Procedure

Children in this study were brought to the hospital's radiology department by their parents or other close relatives (hence referred to as parent) after being seen at the hospital's primary care clinic or emergency room. Children who met the inclusion criteria and their parents were told about the research and asked whether they would want to participate when they arrived at the radiology department. The children were then individually questioned in a quiet area near to the examination room to get their thoughts on the x-ray procedure. The kids were also given the Colored Analogue Scale (CAS) to assess the severity of their pain and the Facial Affective Scale (FAS) to rate their level of distress. The children's post-radiographic self-measurements were reported as having been taken at the time of the radiographic examination.

Informed consent

The patient's family members gave their written approval after receiving information about the procedure. The patients' families were given information about the trial. People above the age of 12 provided their informed consent.

Data Analysis

SPSS (IBM, SPSS Statistics version 25) was used for the statistical analysis. Kappa statistics were used to determine the degree to which CXR and CUS agreed in their ability to identify abnormal symptoms. By calculating their respective sensitivities, specificities, PPVs, and NPVs, we compared the diagnostic efficacy of bedside chest ultrasonography with that of bedside Chest Radiography (CXR). Quantitative information was presented as frequency and percentage displays of qualitative data. Quantitative information was summarized using mean and standard deviation. McNemar test for paired data was used to determine significance. Statistical significance was defined as a probability value less than 0.05.

Chest Ultrasound Protocol

Three longitudinal lines (parasternal, anterior axillary, and posterior axillary) and two axial lines (one above the diaphragm and another immediately above the nipples) were used to split each hemithorax into six equal pieces. The sternum and the anterior axillary line define the anterior portion of each hemithorax, whereas the lateral axillary line and the posterior spine define the posterior portion. Perpendicular to the ribs, the probe was positioned to examine both halves of the chest. Starting at the diaphragm and working our way to the apex, we examined each hemithorax in this order: (1) anterior, (2) lateral, and (3) posterior [16, 17] (Fig. 1).

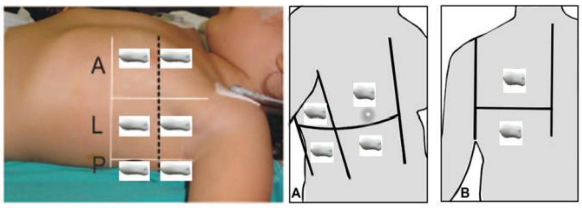

Figure 1: The six sub-regions of each hemithorax and the locations of the US probe

Measurements

Cohen's kappa (k) statistics were used to assess the level of agreement between CUS and CXR tests in the detection of abnormalities. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy were used to evaluate CUS's diagnostic performance in comparison to CXR.

RESULTS

One hundred of them were good results. There were 6 false positives and 20 false negatives, with only 14 instances of the correct diagnosis.

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Table 1: Diagnosis of patients suspected of needing heart surgery using ultrasonography and surgical findings

Ultrasonography	Surgical findings		Total
	Positive	Negative	
Positive	100 (TP)	6 (FP)	106 (76%)
Negative	20 (FN)	14 (TN)	34 (24.0%)
Total	120	20	140

Table 2 shows that ultrasonography's sensitivity, specificity, positive predictive value, negative predictive value, and accuracy in detecting pediatric cardiac surgery were 82%, 79%, 98%, 31%, and 82%, respectively [11].

Table 2: Diagnostic Accuracy of Chest Ultrasound Using Surgical Results as the Gold Standard in Children with Suspected Heart Surgery

Parameter	Estimate	95% CI
Sensitivity	82	69.3 to 90.7
Specificity	79	37.2 to 98.7
Positive predictive value	98	89.7 to 99.9
Negative predictive value	31	10.7 to 57.7
Diagnostic accuracy	82	65.7 to 97.3

Table 3 provides estimated radiation exposures for frequent pediatric radiological examinations. Due to the low predicted cancer risks, a real quantitative risk estimate is only possible with extremely large sample sizes and lengthy durations of follow-up from epidemiological research. These studies are notoriously difficult to carry out because of the many variables involved, the diversity of the populations being studied, the potential for lost follow-up, and other logistical challenges [16].

Table 3: Estimated comparative effective doses of commonly used radiological investigations, for a 1 month to 18 years old

	Effective dose (mSv)	Equivalent CXR (0.04 mSv)	Equivalence to NBR (2.6 mSv/yr.)
Chest XR	0.03	1	6 days
Skull XR	0.05	1.4	9 days
Lumbar spine XR	0.43	12	2 months
Abdominal XR	0.3	11	2 months
DMSA	1.1	24	4.5 months
MAG-3 renogram	0.6	17.4	3.4 months
MCUG (boys)	1.4	37.4	6.8 months
Barium swallow	1.1	24	6.8 months
CT head	2.1	49	9 months
CT chest	2.4	62.4	11.3 months
CT abdomen/pelvis	5.1	124	22.6 months

CT is for computed tomography; CXR stands for chest radiograph; DMSA stands for DiMercapto Succini acid nuclear medicine evaluation; MAG-3 stands for Mercapto Acetyltri Glycine renogram; MCUG stands for micturating cystourethrogram; NBR stands for normal background radiation (UK average); and XR stands for radiograph, anteroposterior unless otherwise specified.

Ninety-three CXRs were normal among a total of 140. In 47 chest x-rays, the surgeon saw anything out of the ordinary. Seventy-two of the CUS investigations found nothing out of the ordinary, whereas 68 did. Sixty-nine trials had normal results from both CUS and CXR. There were 44 research that found the same aberrant results using both methods. Twenty-four trials labeled abnormal by CUS were deemed normal by CXR, while the reverse was true in three investigations.

Table 4: A study comparing CUS and CXR Diagnosis of Normal and Abnormal Conditions

		Chest X-Ray		Total no. of Study (n)
		Abnormal (n) (+)	**Normal (n) (-)**	
Chest Ultra-Sound	Abnormal (n) (+)	44	24	68
	Normal (n) (-)	3	69	72
Total		47	93	140

Kappa statistics revealed a very high level of agreement, with a Kappa coefficient of K=0.749 (p <0.0001). CUS has a sensitivity of 96.9% specificity of 84.75%, PPV of 73.4%, and NPV of 98.43%.

Table 5: CXR and CUS diagnoses were used to determine the percentage and total number of studies included in each category

Findings in CXR and CUS	Number of Studies
Normal CXR and CUS	69
Abnormal CXR and CUS	44
Normal CXR and abnormal CUS	24
Abnormal CXR and normal CUS	3

CUS and CXR concordance; sensitivity, specificity, PPV, and NPV of CUS in the first postoperative day were analyzed.

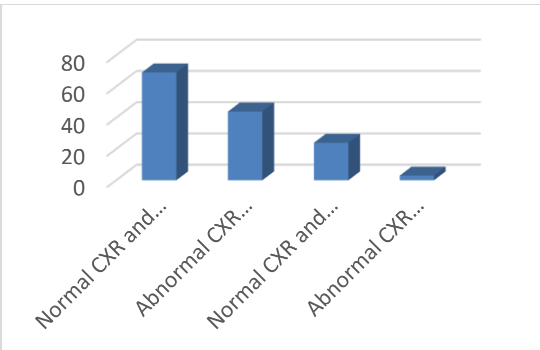

Figure 2: A Study Comparing CUS and CXR Diagnosis of Normal and Abnormal Conditions

DISCUSSION

Significant morbidity and death are caused by postoperative respiratory dysfunction. Since post-operative cardiac surgical patients with inotropic supports and chest drains cannot be moved out of ICU to the radiology suite, bedside CXR is taken as standard reference of care [6]. Radiation exposure will increase proportionally with the increase in the number of CXRs required. A majority of ICUs have access to portable ultrasonography (USG) devices. Even though it has been shown to aid in diagnosis and treatment [7], CUS is not widely used in ICUs. CUS is a practical imaging modality for perioperative treatment due to its noninvasive nature, absence of radiation exposure, and speedy availability.

Several studies have compared CUS to bedside CXR for adults in acute care settings. Postoperative research on pediatric cardiac surgery patients is few. As a result, we conducted prospective observational research to evaluate the accuracy and comfort level of CUS diagnosis in relation to CXR. The surgical ICU coworker and the primary investigator made the joint decision to implement the interventions. We predicted that CUS may replace CXR in post-operative cardiac surgery patients for the purposes of diagnosing intrathoracic diseases and monitoring them. CXR and CUS concordance in the postoperative phase was also investigated. The Kappa value was 0.7762 (P<0.0007), showing a high level of consensus. The Kappa value for agreement between CXR and CUS results on postoperative day 1 was k=0.7147 (p= 0.0037), indicating strong agreement between the two methods.

The potential for medical imaging exposure to cause cellular-level genetic alterations is becoming an increasingly pressing problem. Exposure of the mouse brain to >1 mGy in animal models results in the modification of 1500 genes, with dose-dependent genomic modulation reported in 30% of these cases [8, 9]. Synaptic plasticity, ion homeostasis, and signal transduction all underwent early alterations. Myelin and protein synthesis are two examples of metabolic processes that underwent alterations later on. Ionizing radiation suppresses brain signaling activity and activates protective and reparative signaling pathways. Human skin tissue has also been shown to undergo similar transformations, however, intriguingly, these reactions may be short-lived, reverting to normal within 24 hours [8].

Reports of intracellular alterations are the most worrisome aspect of MRI. The permeability and flexibility of erythrocyte membranes and the erythrocyte sedimentation rate (ESR) were shown to vary during MRI in one research [10], although these parameters immediately recovered to normal when the procedure was over. The development of micronuclei (MN) in peripheral blood cells of healthy participants before and after a cardiac MRI scan suggests that MRI may induce DNA damage [11]. The DNA alterations were temporary, since they reversed themselves within 48 hours. Micronuclei in lymphocytes have been proposed as a predictive biomarker of cancer risk [12], which is reason for worry. Since it has been shown that the exposure of nematode worms (C. elegans species) to static fields of above 3T causes the upregulation of many genes [13], several scientists are looking into whether or not this also occurs in healthy human patients.

Limitations of the study

a. Reasons for not promoting costly techniques like MRI are naturally rehearsed when resources are limited; these include the need for extensive examination times, skilled technicians, and radiologists to correctly interpret images; however, these arguments could have been made regarding the introduction of any new or evolving technique, including CT.

b. Due to a lack of access to portable ultrasonography, this research did not look at cases of suspected minor pneumothorax in children. There was no way to get these youngsters to the ultrasound room because of how ill they were and how fragile they were.

c. Postoperative patients have a smaller study area for CUS because of bandages and drains.

Scope and suggestions for future research

Although it is hard to know for sure, it is probable that today's kids will get more imaging investigations throughout their lives than their parents had. Given that many of these in adulthood may include computed tomography (CT), the rational strategy is to strive to reduce radiation dosage in infancy, both for the individual and the community as a whole [14, 15]. Cumulative low-dose ionizing radiation poses a minor but compelling harm to children, according to the best available research. Although there is new data suggesting MRI and ultrasound may have unanticipated impacts, it seems sense to explore non-ionizing-based procedures wherever feasible, given our forecasts for the children examined today. We need to regularly assess how our methods stack up against the most recent findings in the sciences as our understanding grows. Acquiring high-resolution portable ultrasound technology will expand sonography's use in the care of critically sick patients at the bedside. More education is required for the non-invasive method of intussusception reduction.

CONCLUSION

Investigating a youngster who has been vomiting with ultrasound may help rule out many of the most prevalent juvenile diseases and conditions. Due to its excellent diagnostic accuracy, specificity, sensitivity, negative and positive predictive values, and positive likelihood ratio, ultrasonography is trustworthy for diagnosing Cardiac Surgery in children. Pneumothorax, pleural effusion, atelectasis, and interstitial edema were all more easily diagnosed with CUS than with CXR. For patients with interstitial edema and atelectasis, CUS was also shown to be more accurate than CXR in gauging the effectiveness of treatment. We conclude that chest ultrasonography might be a superior alternative to bedside chest X-ray as a diagnostic and monitoring tool in post operative pediatric cardiac surgery patients since it identified more intrathoracic diseases than CXR. It eliminates the need for patients and medical workers to be exposed to radiation and may be readily repeated if there is a change in the patient's clinical status. The present state of knowledge implies that even a single dose of ionizing radiation in children poses a tiny but compelling risk of gene expression alterations that might eventually lead to cancer. Although there is growing evidence that other imaging methods, including MRI and USS, may also have minor unknown long-term negative/adverse consequences, it appears acceptable to seek non-ionizing-based procedures whenever feasible, given our projections for the children examined today.

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