Journal Reading

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Accuracy of Point-of-Care Ultrasound for Diagnosis of Skull Fractures in Children

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Introduction

- Head trauma is one of the most common childhood injuries
- Skull fracture is associated with a 4X increased risk of intracranial injury
- The gold standard diagnostic test for skull fracture is CT
  - Radiation
  - Need sedation

Introduction

- Point-of-care ultrasound is widely accepted as a diagnostic tool for use in the ER
- Ultrasound is well tolerated by children even in areas of injury
- The study's principal objective
  - Determine the test performance characteristics
  - Point-of-care ultrasound vs. CT scan
  - Diagnosis of skull fractures in children

Method

- Study Design and Setting
  - Inclusion
    - Patients <21 years of age
    - With head injuries requiring CT scan for suspected fracture and/or intracranial injury
  - Exclusion
    - Completed radiologic studies
    - A confirmed skull fracture
    - An open fracture,
    - Urgent intervention was required

Method

- All enrolling PEM attending and fellow physicians attended
  - a 30-minute didactic session to learn how to use ultrasound to evaluate the skull for fracture
  - a 30-minute hands-on practical session
- All study sonologists except for one were novices to musculoskeletal ultrasound at the start of the study

Method

- The transducer was placed over the area
  - Soft tissue swelling
  - Hematoma
  - Point of impact
  - Point of maximal tenderness

  - A PEM physician with expertise in ultrasonography (J.W.T.), who has >10 years of point-of-care ultrasound clinical and teaching experience reviewed all recorded ultrasound scans

Method

- The gold standard for skull fracture was defined as “fracture” or “cortical irregularity” as documented in the attending radiologist’s report of the head CT

Method

- Primary outcome
  - test performance characteristics

  - Point-of-care ultrasound performed and interpreted by trained PEM physicians
    - compared with
  - CT scan with clinical follow-up

Method

- Secondary Outcome
  - Compare interobserver agreement between enrolling PEM physicians and an expert PEM sonologist
  - Combined data with published studies that used similar methodology and perform a pooled-analysis

Results

- Sixty-nine patients with a mean age of 6.4 years were enrolled

TABLE 1 Patient Demographic Characteristics

	n (%)
Male	45 (65)
Scalp hematoma	43 (62)
Frontal	9 (13)
Temporal	8 (12)
Temporal and parietal	2 (3)
Parietal	11 (16)
Parietal and occipital	1 (1)
Occipital	11 (16)
Location not noted	1 (1)
Loss of consciousness	9 (13)
Vomiting	22 (32)
GCS <15 or altered mental status	8 (12)
Palpable fracture	4 (6)

N = 69. GCS, Glasgow coma scale.

Results

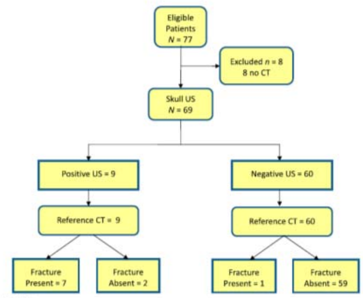


FIGURE 2
STARD (Standards for Reporting of Diagnostic Accuracy) flowchart.

Results

- Fracture was diagnosed by the enrolling sonologist in 9 patients
- 3 (4%) discordant results between point-of-care ultrasound and radiographic imaging,
  - 1 falsenegative result
  - 2 false-positive results

Results

- The false-negative case
  - a 7-month-old male
  - Presented with a temporal scalp hematoma after head trauma

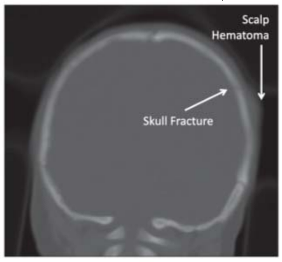


FIGURE 4
Coronal CT scan of a skull fracture adjacent to scalp hematoma missed on point-of-care ultrasound.

Results

- The false-positive case

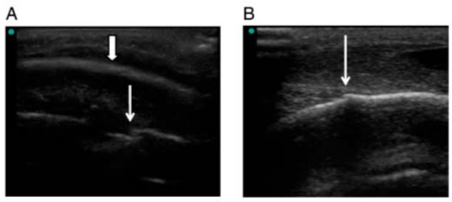


FIGURE 5
A, Negative skull ultrasound (thick arrow) incorrectly interpreted as a fracture (thin arrow) by the PEM physician. B, Skull fracture (arrow) visualized on point-of-care ultrasound and not detected by head CT.

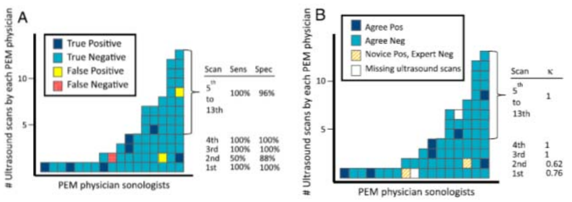
Results

TABLE 3 Test Performance Characteristics for Point-of-Care Ultrasound Diagnosis of Skull Fractures

	N	Fractures, *n* (%)	Sensitivity, %	Specificity, %	PPV
Overall	69	8 (12)	88 (53–98)	97 (89–99)	0.78 (0.45–0.94)
Novice sonologists	57	8 (14)	88 (53–98)	96 (86–99)	0.78 (0.45–0.94)

	NPV	LR+	LR−	κ
Overall	0.98 (0.91–1.0)	26.7 (6.7–106.9)	0.13 (0.02–0.81)	0.86 (0.67–1.0)
Novice sonologists	0.98 (0.89–1.0)	21.4 (5.4–85.4)	0.13 (0.02–0.82)	0.85 (0.66–1.0)

Results



Results

TABLE 4 Pooled-Data Analysis of Point-of-Care Ultrasound for Skull Fracture Diagnosis

Study (Reference)	*N*	Fractures, *n* (%)	Sensitivity, %	Specificity, %	LR+	LR−
Weinberg et al (15)	21	2 (10)	100 (20–100)	100 (79–100)	Infinity (2.1–infinity)	0 (0–2.15)
Riera and Chen (19)	40	5 (13)	60 (17–93)	94 (79–99)	10.5 (2.3–48.2)	0.42 (0.15–1.25)
Parri et al (18)	55	35 (64)	100 (88–100)	95 (75–100)	13.8 (3.0–64.6)	0.02 (0–0.24)
Rabiner et al	69	8 (12)	88 (53–98)	97 (89–99)	26.7 (6.7–106.9)	0.13 (0.02–0.81)
Total pooled data	185	50 (27)	94 (84–98)	96 (92–98)	25.4 (10.7–60.2)	0.06 (0.02–0.19)

Data are test performance characteristics (95% CI). LR+, likelihood ratio of a positive test; LR−, likelihood ratio of a negative test.

Discussion

- 1-hour, focused musculoskeletal ultrasound training session
- Novice sonologists are able to quickly and accurately diagnose skull fractures with high specificity

Discussion

- Ultrasound advantages
  - Ultrasound can be performed rapidly
  - Has the potential to reduce CT use and ionizing radiation exposure in children
  - Without the need for sedation
  - Better availability
  - Triage in mass casualty disasters
- Ultrasound disadvantages
  - intracranial injury may occur without skull fracture

Discussion

- Ultrasound may diagnose minimally or nondisplaced skull fractures that can be missed on CT scan
- Knowledge of suture anatomy is essential in performing ultrasound examinations of infant skulls

Discussion

- Negative fracture in sonography
  - Do CT?
- Novice group of sonologists was trained to perform skull ultrasound with such high specificity

Discussion

- There is a missed fracture
  - Due to a skull fracture that was *adjacent* to but not *directly beneath* the scalp hematoma
  - Now recommend scanning the areas around the scalp hematoma

Conclusion

- Clinicians with focused, point-of-care ultrasound training were able to diagnose skull fractures in children with head trauma with high specificity
- Almost perfect agreement was observed between novice and expert
- Future research is needed to determine if ultrasound can reduce the use of CT scans in children with head injuries

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Original Contribution

Role of inferior vena cava and right ventricular diameter in assessment of volume status: a comparative study
Ultrasound and hypovolemia

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Introduction

- Early detection of hypovolemia and prompt institution of therapy may save lives
  - Physical examination findings
  - Hematocrit levels
  - Biochemical markers
  - Central venous pressure (CVP)

Introduction

- Ultrasonography may be used as an effective tool in the detection and management of hypovolemia
  - Fast
  - Repeatable
  - Applicable at the bedside

Introduction

- Ultrasonographic measurement of the diameter of inferior vena cava (dIVC) to detect hypovolemia has become popular
- In this study
  - Investigated the efficacy of the ultrasonographic evaluation of IVC and right ventricle (RV) diameters in the diagnosis and treatment of hypovolemia

Materials and Methods

- Patients
  - With dry mucosa, reduced skin elasticity, cool extremities, lengthened capillary refill times, tachycardia, reduced urine output, orthostatic hypotension, and fatigue
  - Hypovolemia is anticipated
    - abnormal uterine bleeding, gastrointestinal bleeding, diarrhea, and vomiting

Materials and Methods

- Control Group
  - healthy volunteers
    - such as patient relatives and medical personnel

Materials and Methods

- Exclusion
  - Ultrasonographic measurements could not be performed
    - because of technical and anatomical reasons, eg. Obesity, gas
  - Tricuspid failure, right-sided heart disease, portal hypertension, and obstructive lung disease
  - Intubated patients

Materials and Methods

- Physisians
  - 8 hours of theoretical and applied focused echocardiography training and 8 hours of basic emergency ultrasonography training were given
  - IVC and RV diameters were measured in 15 hypovolemic patients and 15 healthy volunteers in the presence of a expert

Materials and Methods

- Inferior vena cava diameters were checked in the supine position at 5-MHz frequency with M-mode
- Probe was placed in the subxiphoid location, and the sagittal section of the IVC was imaged

Materials and Methods

- dIVC was performed at 2 cm caudal of the junction point of the hepatic vein and IVC
- Inspiratory (dIVCi) and expiratory (dIVCe) diameters of the VCI were detected
  - The caval index (CI) (CI = dIVCe − dIVCi/dIVCe) was calculated as the IVC provided respiratory variance

Materials and Methods

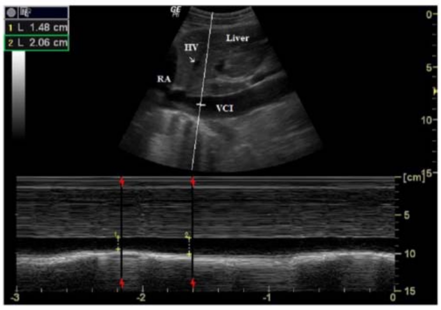

Fig. 1. Measurement of the dIVC in a patient in the control group. The dIVCe and dIVCi are 2.06 and 1.48 cm.

Materials and Methods

- The diameter of the RV (dRV) of the patients was measured at supine left lateral decubitus position with B-mode at 3.2-MHz frequency
- The probe was placed between the third and fourth intercostals spaces
- Long-Axis view of heart

Materials and Methods

- First moment the mitral valve started to close was considered as the end of diastole, and measurements of dRV were performed at this time point
- Measuring RV lumen under the tricuspid valve from the interior wall to the opposite interior wall is recorded as dRV

Materials and Methods

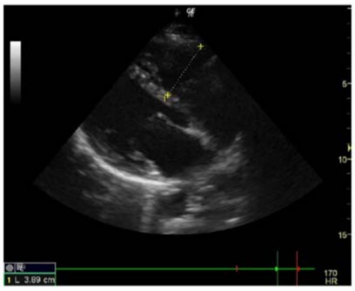

Fig. 2. Measurement of the dRV in a patient in the control group. The dRV is 3.89 cm.

Materials and Methods

- Treatment
  - 1000 ml of 0.9% isotonic NaCl solution
  - After the intravenous fluid, all measurements were repeated

Results

Table 1
Comparison of parameters measured of the patient and control groups

	Patient group, pretreatment	Patient group, posttreatment	Control group	P^{a*}/P^{b**}
Age (y)	57.1 ± 16.8		56.3 ± 16.8	.821
SBP (mm Hg)	94.30 ± 13.2	113.3 ± 9.6	123.9 ± 15.6	**.000/.000**
DBP (mm Hg)	55.7 ± 12.2	66.6 ± 8.7	69.3 ± 11.1	**.000/.000**
Pulse (pulse/min)	104 ± 15.1	93.4 ± 12.2	80.8 ± 11.6	**.000/.000**
dIVCi (cm)	0.73 ± 0.37	1.01 ± 0.44	1.32 ± 0.35	**.000/.000**
dIVCe (cm)	1.27 ± 0.43	1.55 ± 0.41	1.81 ± 0.38	**.000/.000**
CI (cm)	0.44 ± 0.17	0.36 ± 0.14	0.27 ± 0.12	**.000/.000**
dRV (cm)	2.83 ± 0.37	3.09 ± 0.33	3.11 ± 0.41	**.000/.000**

P^a/P^b, Patient group pretreatment vs posttreatment/control group.
* Paired *t* test.
** Independent samples *t* test.

Results

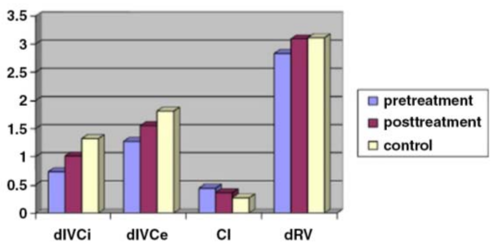

Fig. 3. Comparison of dIVCi, dIVCe, CI, and dRV measurements in the hypovolemic group (pretreatment/posttreatment) and the control group.

Discussion

- Hypovolemia and hypovolemic shock must be diagnosed and treated promptly in the EDs
- CVP measurement is a frequently used method
  - measurement of CVP is an invasive procedure
  - Recent studies showed CVP is not an ideal method
- Physical examination
  - may be found normal as the compensatory mechanisms
  - Baseline unknown

Discussion

- Another study performed on blood donors suggested that the serial measurement of IVC diameters may be used to follow ongoing blood loss and evaluate the response to Tx
- A correlation existed between blood pressure and pulse in the hypovolemic group, none existed in the control group

Discussion

- The results we obtained in this study reveal that
  - IVC and RV diameters may be beneficial for the early detection of hypovolemia and in the follow of fluid replacement.
  - The dIVC and dRV are more sensitive than conventional parameters (such as BP and HR) in diagnosing hypovolemia.

Discussion

- Limitations
  - Some diseases (tricuspid failure, right cardiac diseases, portal hypertension, and obstructive lung disease) impact the RV and IVC diameter
  - The important limitation of the study is also the definition of hypovolemia using conventional clinical findings
  - All measurements in each patient were done by the same physician
    - Intraobserver variability was not evaluated

Conclusion

- Bedside serial ultrasonographic measure of RV and IVC diameters
  - may be a useful tool to detect and follow-up hypovolemia and evaluate the adequacy of volume replacement

- Thanks very much!