Three-Dimensional Computed Tomography Skull Reconstructions as an Aid to Child Abuse Evaluations

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Objectives: Skull fractures can be difficult to recognize on radiographs and axial computed tomography (CT) bone windows. Missed findings may delay abuse diagnosis. The role of three-dimensional (3-D) reconstructions in child abuse evaluations was retrospectively evaluated.

Methods: Twelve exemplary cases between August 2006 and July 2009 are described. All, except 2 medical-legal cases, were clinical abuse consultations. With the use of a 1-to-3 scale, ease and accuracy of interpretation of findings between plain films, bone windows, and 3-D CT images were independently assessed by 2 radiologists.

Results: In 7 cases, skull fractures were missed on initial review of skull films and/or bone windows. Three children sustained additional abusive injury before 3-D CT reconstructions demonstrated subtle skull fractures, though imaged, were missed on initial readings. Three children with initially unrecognized fractures had timely 3-D reconstructions confirming fractures, allowing protective intervention before additional injury. An unrecognized ping-pong fracture was discovered on 3-D reconstructions with an inflicted subdural hemorrhage, defining the injury as an impact. Two 3-Ds demonstrated communication of biparietal fractures along the sagittal suture. This changed interpretation to single, rather than 2 separate, concerning impacts. Three potential skull fractures were found to represent large sutural bones. In all cases, ease and accuracy of interpretation scores were highest for 3-D CT.

Conclusions: Without increasing patient radiation exposure, 3-D CT reconstructions may reveal previously unrecognized skull fractures, potentially allowing abuse diagnosis before additional injury. They may clarify normal skull variants and affirm accidental injury causes. We now routinely include 3-D reconstructions on cranial CTs for children younger than 3 years.

Key Words: child abuse, skull fractures, missed diagnosis of abuse, cranial computed tomography, 3-D reconstruction

(*Pediatr Emer Care* 2015;31: 779–786)

Missed radiology findings are recognized to be one issue leading to delay in the diagnosis of abusive head trauma (AHT) and skeletal trauma.[1,2] Although no individual finding should cause such missed diagnoses, the most complete and accurate understanding of what injuries are present can aid the evaluation of suspected child abuse. In the absence of a definitive diagnosis of a skull fracture, some imaging findings, such as increased size of extra-axial cerebrospinal fluid spaces might be interpreted as benign variants, rather than traumatic injuries. Skull fractures can be difficult to recognize on plain skull films and cranial computed tomography (CT) bone windows.[2–4] Moreover, in young infants, it is difficult to be sure whether lucencies around the posterior fontanelle represent fractures or sutural bones. Although skull fractures frequently result from accidental infant injuries, they are also a common component of AHT.[5] Our institution experienced several cases in which skull fractures were not recognized at the time of the initial two-dimensional (2-D) CT interpretations. Subsequently, some of these children sustained additional severe inflicted injuries. Three-dimensional (3-D) reconstruction of cranial CT bone windows from subsequent CT scans revealed fractures which, in retrospect, had been subtly present on the initial imaging. Exemplary cases in which such 3-D reconstructions clarified uncertain findings or revealed abnormalities not recognized on plain skull films and/or CT bones windows are presented.

METHODS

We present a nonconsecutive case series of 12 children who had 3-D CT skull reconstructions. The children were evaluated between August 2006 and July 2009. They are a minority of the children who had 3-D reconstructions during this time period and are not all the children for whom reconstructions were helpful. Instead, they were chosen to illustrate how missed skull fractures can affect management decisions and how 3-D reconstructions can aid recognition of traumatic and nontraumatic skull findings. We chose these cases to represent (1) how, after the fact, 3-D imaging identified previously missed skull fractures in children who were subsequently reabused; (2) how fractures that initially were missed in abused children were recognized by 3-D in time to intervene protectively; (3) how 3-D clarified the presence and/or extent of complex fractures, clarifying their cause; and (4) how normal skull variants, initially suspected to represent fractures, were recognized. We describe the ease of recognizing these children's abnormalities using various imaging modalities. Ten children were identified through clinical child abuse consultation at the time of their diagnostic evaluations at either Seattle Children's or Harborview Medical Center in Seattle, Washington. Two cases arose from medical-legal consultations.

For children younger than 2 years, noncontrast CT head scans were performed with the patient supine in the gantry, with imaging extending from the skull base to vertex, with the reconstruction angle parallel to the supraorbital meatal line, using the following parameters: helical acquisition; 120 kV; 310 mA; total scan time, 0.4 seconds; pitch 0.969:1; scan field of view, small head; display field of view, 20 cm; and neurofilter 2. Images were reconstructed as follows: 3.75 mm axial soft tissue; 1.25 mm axial bone; 0.625 mm standard for 3-D reconstruction by Vitrea algorithm.

Images were displayed at the following window width and window levels Hounsfield units to best demonstrate the following structures:

$$\text{Brain: } WW = 70-90\,HU;\, WL = 30-50\,HU$$

$$\text{Bone: } WW = 2500-4000\,HU;\, WL = 200-700\,HU.$$

$$\text{Blood: } WW = 180-200\,HU;\, WL = 60-100\,HU.$$

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Disclosure: The authors declare no conflict of interest.
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ISSN: 0749-5161

TABLE 1. Characteristics of Children for Which 3-D Skull Imaging Aided Their Evaluation

Age, mo	Presenting Concern	Initial Clinical Skull Interpret	Initial Clinical CT Interpretation	3-D Interpretation	Other Injuries	Ease of Reading Films*	Consequence for Child
9.7	FTT	Not done	Increased SD and SA fluid bilateral, skull and scalp nl	L occipital-parietal diastatic skull Fx	R distal humerus periosteal reaction	Dx Skull—0 CT-BW—2 3-D—3	Readmit at 10.2 mo for 2nd abusive head/brain injury
34.4	L hemiplegia s/p stair fall	Not done initially, later nl	R SDH, parenchymal infarcts, nl scalp and skull	L parietal Fx	Distal L radius and base 1st L metacarpal Fxs, L humerus, R ulna periosteal layering	Dx Skull—1 CT-BW—1 3-D—2	Readmit at 35.3 mo New abusive head/brain injury
3.9	Rapid OFC increase; FTT	Not done	Bilateral extra-axial fluid—possible SDE, scalp and skull nl, no acute blood MRI recommended by radiologist, but not done	Biparietal Fxs	Bruising healing L 9th rib Fx	Dx skull—0 CT-BW—2 3-D—3	Abuse not diagnosed Readmit at 8.6 mo for inflicted gastric rupture
4.5	Fussy, not use L leg intertrochanteric femur Fx	R parietal Fx vs variant suture	Nl	R and L parietal Fx	Callused R midclavicle Fx	Dx skull—2 CT-BW—2 3-D—3	Fx recognized during initial hospitalization, child protected
4.1	Increasing OFC	Completed later-diastatic R parietal Fx	Probable bilateral SDE, normal skull and scalp	Horizontal diastatic R parietal Fx	Retinal hemorrhage	Dx skull—3 CT-BW—2 3-D—3	Skull Fx recognized later in same clinic visit, child protected
7.6	Fall from table, epistaxis, lump on head	Not done	Contact R SDH, separate L occipital and R parietal Fxs Swollen scalp	2 Fxs recognized to communicate along sagittal & lambdoid sutures	Interpretation as single accidental fall impact injury	Dx Skull—0 CT-BW—2 3-D—3	Diagnosed as accidental contact injury from fall
1.1	Lethargy oral blood, then projectile vomiting	Completed later-diastatic L parietal horizontal Fx	Bilateral extra-axial fluid—possible L parietal parenchymal lucency, intraventricular and post-fossa blood, nl scalp and skull	Grossly split sutures and diastatic L parietal Fx,	Frontal encephalomalacia, retinal hemorrhage	Dx skull—2 CT-BW—2 3-D—3	Abuse recognized during initial hospitalization, child protected
10.2	Vomiting lethargy	Nl	L frontal-parietal and tentorial SDH with mass effect, no Fx or scalp swelling	Ping-pong Fx anterior L parietal	Retinal hemorrhage	Dx skull—1 CT-BW—2 3-D—3	Medical interpretation changed to abusive head injury including impact trauma.
1.8	Inflicted tibia Fx	Not done	Possible L posterior parietal Fx arising from lambdoid, scalp nl, mild suture diastasis	No skull Fx, large L posterior wormian bone	Healing L post-lat 7th rib and tibia spiral Fxs, FTT	Dx skull—0 CT-BW—2 3-D—3	Interpretation changed to FTT and inflicted Fxs, but no skull Fx

4	Decreased use of L arm after dad accidentally twisted arm	Nl	Possible Fx running perpendicular to lambdoid in posterior L parietal, Nl scalp	Child recognized to have isolated inflicted L humerus Fx	Oblique L midshaft humerus Fx	Dx skull—1 CT-BW—2 3-D—3	Large L posterior wormian bone Interpretation—abusive arm Fx alone
2.3	Swollen scalp—felt to be cystic, posterior, crossing sagittal suture	Skull Fx	Possible L posterior parietal fracture, large focal scalp fluid mass	Interpretation changed to nontraumatic scalp cyst, no skull fracture	None	Dx skull—2 CT-BW—2 3-D—3	Large, predominately L sided sutural bone, scalp cyst Abuse excluded
14.7	Crying, R scalp swollen.	Not done	Extensive skull Fxs—R parietal and complex occipital—possible multiple impacts, scalp swollen	Interpretation changed to injury compatible with single impact/fall	None	Dx skull—0 3-D—3 CT-BW—2	Skull Fxs all connected, accepted as single injury, but CPS involved because no injury history

*For the column: "Ease of reading films" these numbers are the result of the study radiologists' retrospective review. Coding for these: 0 = not done, 1 = done, skull findings not identified, 2 = done, findings identified with difficulty, 3 = done, findings readily apparent.

Fx indicates fracture; CT-BW, computed tomography bone windows; 3-D, 3-D skull reconstruction from computed tomographic bone windows; R, right; L, left; Dx skull, diagnostic skull film; Nl, normal; FTT, failure to thrive; OFC, occipital-frontal circumference; SDH, subdural hemorrhage; SDE, subdural effusion; MRI, magnetic resonance imaging; s/p, status post.

With the use of these parameters, our typical CT dose index volumes are 23.73 mGy, substantially less than the maximal 75 mGy allowed for an adult head CT, which is the reference level used by the American College of Radiology. Currently, there are no American College of Radiology reference levels or pass/fail criterion CT dose index volumes for pediatric head CTs.

The 3-D images are computer reconstructions generated from the single initial acquisition and did not result in additional radiation exposure to the patient. Moreover, these reconstructions can be generated by the technologist in less than 5 minutes while initial 2-D images are being reviewed.

Two radiologists experienced in cranial CT evaluation independently and retrospectively evaluated these children's CT scans, including 2-D bone windows, 3-D reconstructions, and their plain skull radiographs. They reviewed the films naive to the initial and subsequent radiology readings. Presence or absence of evidence of skull fractures and ease of interpretation of skull findings was documented for each cranial imaging modality available for each of these 12 patients.

This study was approved by the institutional review board of Seattle Children's.

RESULTS

Abused Children With Skull Fractures Missed by Conventional Imaging

In 7 cases, skull fractures were not recognized on the initial clinical radiology interpretation of plain film skull radiographs (2 children) and/or CT bone windows (all 7 children) (Table 1).

Fractures Missed, Children Reabused

Three of these abused children sustained additional AHT before subsequent CT imaging with 3-D reconstructions demonstrated that the children had had unrecognized skull fractures at the time of their initial imaging (Figs. 1A–D and 2A–D). The fractures were subtle, but present in retrospect, on the initial 2-D CT imaging of two children. The third child only had evidence of the fracture on the subsequent 3-D imaging.

Fractures Recognized by Timely 3-D Reconstructions, Children Protected

Three other abused children with initially unrecognized fractures had timely 3-D reconstructions which demonstrated the skull fractures, allowing appropriate diagnosis of AHT and protective intervention before any additional injury (Fig. 3A–C).

Ping-Pong Fracture Recognized by 3-D, Abuse Mechanics Clarified

Through 3-D reconstruction, a previously unrecognized ping-pong parietal fracture was discovered in one child with inflicted subdural hemorrhage, defining her head injury as the result of an impact in addition to the previously recognized whiplash. This clarified the medical findings, assisted the medical-legal case, and contributed to a guilty plea.

Three of the mentioned abused children without initial plain films had them obtained later; 1 of these 3 films failed to show the fracture.

Three-Dimensional Clarified Normal Skull Ossification Variants

Possible skull fractures on bone windows in 3 children were easily identified on 3-D reconstructions as sutures defining large

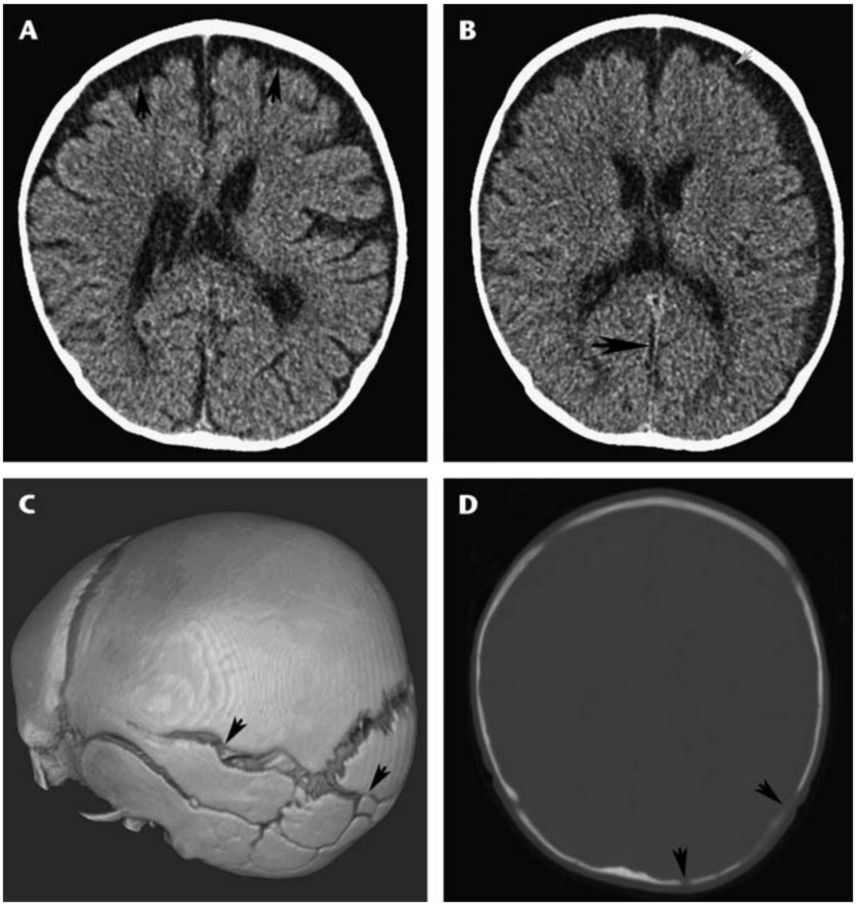

FIGURE 1. A, Axial images from the initial noncontrast CT head scan in a 9-month-old infant with failure to thrive and macrocephaly shows mildly increased bifrontal extra-axial fluid. B, Two weeks later, after a new seizure, axial images from a second noncontrast CT demonstrate acute subarachnoid (gray arrow) and subdural hemorrhages (black arrow) accompanied by sulcal effacement. C, 3-D reconstructions from this study demonstrated complex bilateral parietal-occipital fractures (arrows). D, In retrospect, 2-D bone windows from initial CT evaluation showed a subtle biparietal-occipital fractures [occipital and left parietal fractures (black arrows) on this slice].

posterior parietal sutural (wormian) bones. One infant with failure to thrive was seen at 7 weeks of age for loss of use of his right leg. Healing spiral tibia and left 7th posterior rib fractures were found. Although his bone windows were concerning for a left posterior parietal fracture (Fig. 4A), the 3-D reconstruction showed a large posterior parietal sutural bone (Fig. 4B). He was placed in protective custody because of his other fractures. Another child was evaluated for an inflicted humerus fracture as part of the medical-legal case. The 2-D CT images were interpreted as showing a possible skull fracture. The 3-D clarified that the skull finding was a sutural bone; thus, the arm fracture was an isolated injury. More appropriate testimony resulted. Another child had presented with a fluid-filled mass under the scalp, crossing her posterior sagittal suture. Initially, the radiologist and our emergency department staff interpreted the fluid mass as the result of trauma, with an accompanying parietal fracture. After 3-D reconstruction, it was recognized that a large sutural bone accompanied a benign, atraumatic scalp cyst. As a result, protective services referral was not made.

Three-Dimensional Clarified the Extent and Cause of Complex Fractures

One child was recognized on 3-D reconstruction to have communication of opposite-sided parietal and occipital fractures along her sagittal and lambdoid sutures (Fig. 5A–D). The history was appropriate for a single impact, capable of causing the connecting skull fractures. Thus, the 3-D allowed us to diagnose this case appropriately as an accident as described. Another 14-month-old child, who had presented with unexplained scalp swelling, was initially felt on skull film to have an isolated right parietal fracture. Although the CT bone windows suggested an additional occipital fracture of a different age, the 3-D reconstruction demonstrated that these lucencies all represented a single, complex, interconnected fracture. These findings changed the interpretation of the children's injuries to a single impact, rather than 2 separate impact events. This child was discharged to his parents. However, protective services referral was made to evaluate the day care because the child initially was noted to have the scalp swelling on return from day care, but a trauma history was lacking.

Three-Dimensional Images Compared to CT Bone Windows and Skull Films

In all cases, both radiologists judged it easier not only to identify but also to correctly interpret abnormalities using the 3-D calvarial reconstruction images than either the plain films or CT bone windows (Table 1).

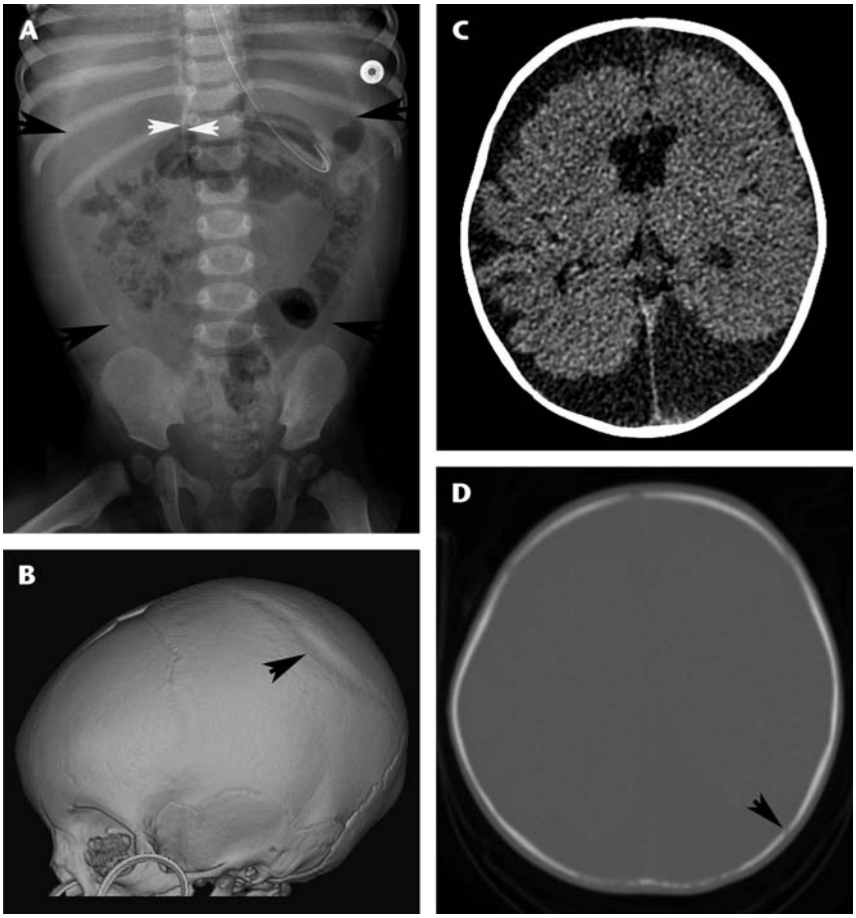

FIGURE 2. A, An 8-month-old female infant had free intraperitoneal air (black arrows), highlighting the falciform ligament (white arrows) from a gastric rupture. B, 3-D CT calvarial reconstructions show healing biparietal skull fractures (arrows). C and D, Previous CT performed for macrocephaly when patient was 3 months of age shows prominent extra-axial spaces (C), and in retrospect a subtle left parietal fracture that had been missed (arrows) on axial bone windows (D).

Detailed Narratives of Some of the Mentioned Exemplary Cases

Case 1: Fracture Missed, Child Reinjured Before Abuse Diagnosis

An 8-month-old infant was evaluated for macrocephaly, failure to thrive and vomiting. A CT scan showed prominent extra-axial fluid spaces (Fig. 1A), but the child was discharged home without further cranial evaluation. Two weeks later she returned with new onset of seizures. Her CT then showed flattened gyri and effaced sulci caused by cerebral edema (Fig. 1B). Additionally, hyperdense small areas of fresh subdural and subarachnoid bleeding were observed. Her findings were indicative of acute on chronic subdural hemorrhage, which was confirmed by magnetic resonance imaging. At this time, a 3-D reconstruction of her skull was done, clearly demonstrating complex bilateral parietal-occipital fractures (Fig. 1C). In retrospect, a subtle left parietal fracture was present, but had been missed, on the initial bone windows (Fig. 1D).

Case 2: Fracture Missed, Child Reinjured Before Abuse Diagnosis

An 8-month-old female presented for abdominal distension and vomiting. A plain film demonstrated free intra-peritoneal air (Fig. 2A). At surgery a traumatic gastric rupture was identified. Three-dimensional CT at that time demonstrated a healing left parietal fracture (Fig. 2B). She also had skin bruising and a healing left 9th rib fracture.

She had been evaluated at 3 weeks of age for failure to thrive and vomiting. A lumbar puncture had yielded xanthochromic fluid. At 3 months of age, she underwent a head CT for evaluation of macrocephaly which was incorrectly interpreted as benign enlargement of her subarachnoid spaces (Fig. 2C). On the subsequent CT obtained when the patient was 8 months of age, these collections were recognized to represent chronic subdural effusions. Although her original CT bone windows had been felt normal, in retrospect, she had a subtle right parietal fracture (Fig. 2D).

Case 3: Fracture Missed, but Recognized in Time for Intervention

A 4-month-old term female who had been the product of a breech cesarean section delivery was referred to the neurosurgery clinic for a rapidly growing head size. Her head size had tracked at 50% until 2 months old, but by her fourth month of checkup her head size had grown to greater than 95%. Between those times she had several brief seizures. She had episodic severe vomiting.

Her head CT showed bilateral subdural effusions (Fig. 3A) with bone windows initially read as normal. By the time the child abuse pediatrician was consulted later that same day, a 3-D reconstruction had been done. This showed dramatic suture diastasis and a horizontal, diastatic left parietal fracture (Fig. 3B). In

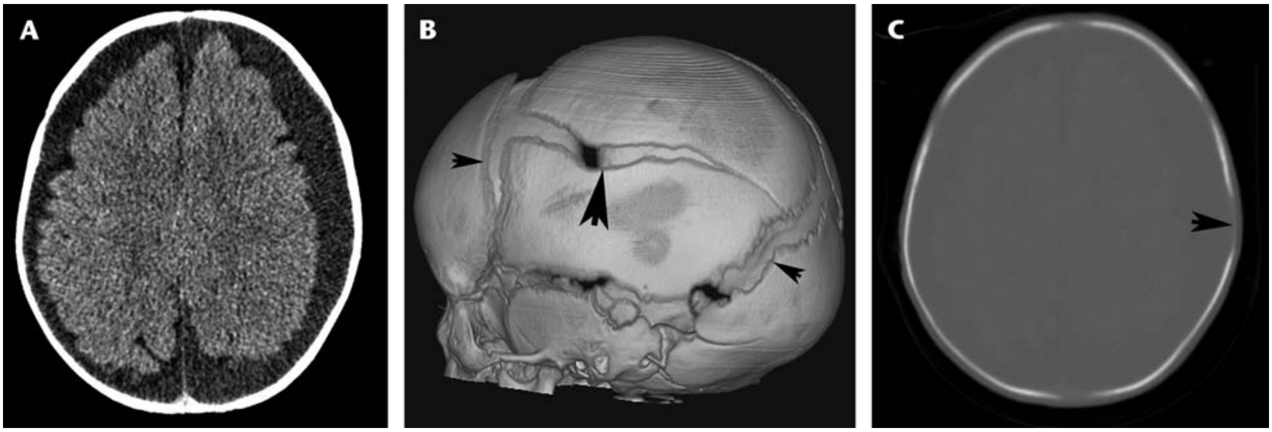

FIGURE 3. A, Axial image from a non-contrast CT in a 4-month-old infant with macrocephaly demonstrated prominent extra-axial fluid spaces. B, 3-D CT showed a large horizontally oriented left parietal fracture (large arrow) and dramatically diastatic sutures (small arrows). C, Initial bone windows had a subtle left parietal lucency (arrow), not initially recognized to be a fracture.

retrospect, a subtle left parietal defect was present on the bone windows (Fig. 3C). Abundant bilateral retinal and pre-retinal hemorrhages were present. Her skeletal survey was otherwise normal.

She was discharged to the protective care of a family member.

Case 4: Abusive Fractures, Concern for Associated Skull Fracture-Normal Suture Variant Revealed

A 6 ½-week-old infant was placed in foster care for admitted abuse by his mother. When the new foster parent took the child for initial evaluation, healing rib and tibial fractures were found on skeletal survey. Cranial CT bone windows also suggested a right posterior parietal skull fracture (Fig. 4A). However, 3-D skull reconstruction images clearly revealed a large posterior parietal sutural (wormian) bone (Fig. 4B). This information avoided incorrect diagnosis of an associated abusive skull fracture.

Case 5: Bilateral Skull Fractures, Concern for 2 Separate Injuries-3-D Revealed Single Communicating Fracture

A 7-month-old infant was reported to have fallen while in a baby bouncer from a kitchen table, without alteration in consciousness. Scalp swelling and a nose bleed rapidly followed. Head CT demonstrated a large impact subdurally (Fig. 5A), directly underlying scalp swelling and a right parietal fracture (Fig. 5B). An additional left occipital fracture noted on bone windows (Fig. 5C) raised the question of 2 separate impacts. On 3-D reconstruction, the fractures were seen to communicate along diastatic sagittal and lambdoid sutures (Fig. 5D). Physical examination, skeletal survey and ophthalmology examination were otherwise normal. The child's injuries were judged consistent with the reported accidental fall.

DISCUSSION

The diagnosis of child abuse can be difficult and has serious implications. On the one hand, missing the diagnosis can subject the child to additional, more serious injuries; and on the other hand, incorrectly diagnosing abuse can lead to potentially harmful state investigation and intervention in nonabusive family situations. As such, our goal should be to narrow the gap in which our diagnosis is uncertain or incorrect in either direction. The better we can identify which injuries the child actually does or does not have, the more likely we are to be successful.

Jenny et al[1] recognized that AHT is frequently (31.2%) missed during a child's initial medical contact. One common reason the diagnosis was missed was that abnormal radiology findings, which were present on the child's imaging, were not recognized in the initial radiology reading for 13% (7/54) of the cases. Six of these

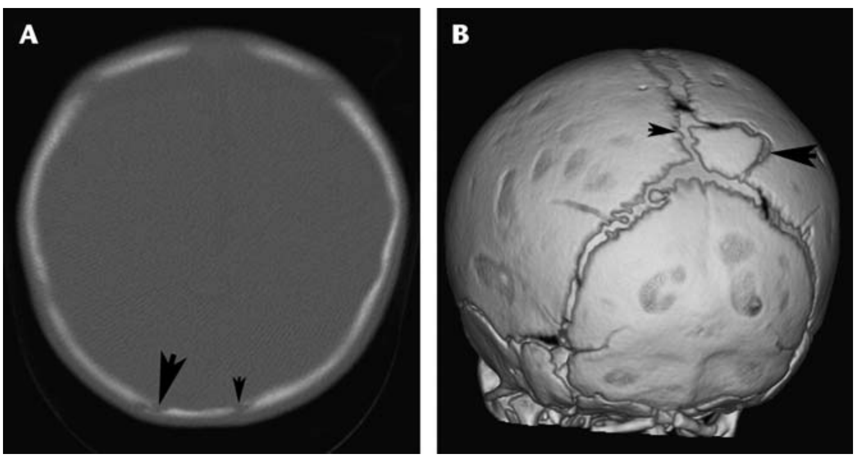

FIGURE 4. A, A 6-week-old child was evaluated after admitted abuse by his mother. CT suggested a right posterior parietal fracture (large arrow) near the sagittal suture (small arrow). B, 3-D CT demonstrated a large posterior parietal sutural bone (arrows) instead of a fracture.

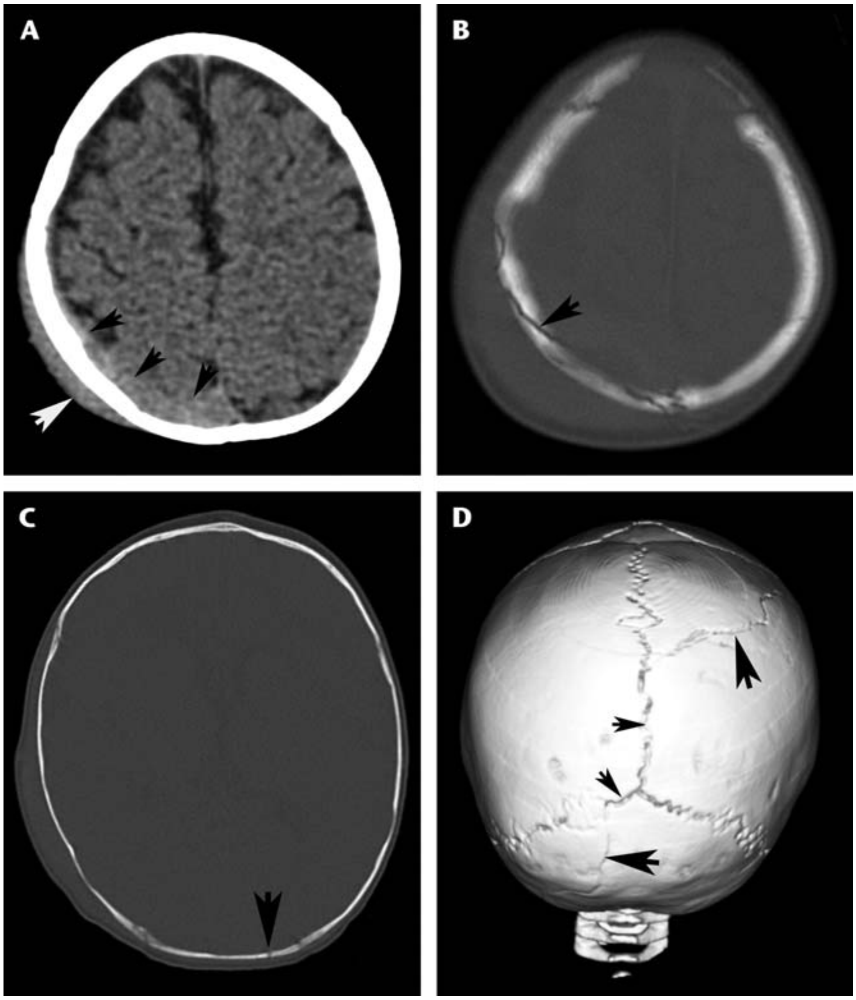

FIGURE 5. A, A 7-month-old infant was reported to have fallen from a table. Axial brain windows demonstrated a large impact subdural (black arrows) and soft tissue swelling (white arrow). B, An adjacent right parietal fracture was present on bone windows (arrow). C, Also noted was an apparently separate left occipital fracture (arrow). D, On 3-D flip view, both fractures (large arrows) could be seen to communicate via mildly diastatic sagittal and lambdoid sutures (small arrows). This was compatible with a single accidental impact.

missed cases included unrecognized cranial CT imaging findings. As a result, in the study of Jenny et al, 27.8% of the children, whose diagnosis had been missed initially, sustained additional injuries before diagnosis. Four of the 5 fatalities among the missed AHT cases were judged as preventable. Similarly, Ravichandiran observed that inflicted fractures were missed in 20.9% of initial medical evaluations.[2] Thirty-three percent of these missed diagnoses were because of missed radiologic findings and 16.7% (18 cases) of all the children in this series sustained additional abusive injuries before diagnosis. Seven of these 18 missed cases involved skull fractures. It is well known that skull fractures that run parallel to the plane of the CT scanner can be particularly difficult to recognize on bone windows.[3]

Our experience, as demonstrated by this exemplary case series, has been similar. In some cases, subtle CT bone window findings were missed on the initial radiology assessment, but were easily visible on subsequent 3-D reconstructions. In some cases, even knowing where to look, based on the 3-D images, the fractures could not be found on the initial bone windows. Several children subsequently had skull films which provided evidence of the fractures, but in some, they also failed to show the injury. Several of these children had undergone CT imaging for an increasing head size, a situation for which it is unlikely that plain skull films would be obtained, unless there is additional concern for injury. Partly, as a result of failing to diagnose the skull fractures on the initial imaging, 3 of the children we report sustained additional serious abusive injuries. In 3 other cases, we were fortunate that 3-D reconstructions were done soon after the initial CT reading, aiding prompt recognition of AHT and intervention to prevent further injury.

Not only were the 3-D reconstructions useful in delineating otherwise missed skull fractures, but they were also helpful in recognizing normal variants, such as unusually large posterior parietal or occipital sutural/wormian bones which mimicked fractures on the bone windows (Table 1). In some cases, this allowed us to exclude abuse, and in 2 children, to recognize that the abuse did not include skull fractures. Additionally, in 2 children, 3-D reconstruction calvarial imaging allowed us to recognize that skull fractures at 2 apparently distant sites were actually extensions of a single impact injury. This allayed our concerns that the child might have sustained 2 separate injuries and instead allowed us to accept that the child had sustained a single accidental cranial impact.

In all our cases, the 3-D imaging demonstrated the findings either as clearly, or more clearly, than the other modalities. Our findings echo the recent report of Prabhu et al.[6] They found the

3-D reconstructions more effectively identified subtle and inscanner plane fractures, allowed recognition of ping-pong fractures, and allowed recognition of normal suture and sutural bone variants. Sanchez et al[7] also found 3-D reconstructions helpful in differentiating skull fractures from accessory sutures. In the study of Prabhu et al,[6] 3-D images changed the initial CT interpretation in 35.6% of studies and changed management for 55.5% of those children whose CT interpretation was altered as a result of 3-D calvarial reconstructions. Mulroy et al,[4] using autopsy as the standard, also observed that CT with 3-D reconstructions were more sensitive and specific for skull fractures than plain films.

In the legal investigation and management of child abuse, it is important to know as accurately as possible the mechanism of the child's injury. Flaherty[8] has observed that initial caretaker histories of abuse often contain partial, but incomplete, versions of the eventually reported or confessed events. Starling et al[9] also reported that when perpetrators confessed shaking alone, some victims still had evidence of head impact trauma, including scalp swelling (6%) and skull fractures (6%). However, such impact evidence was statistically significantly more common when the confession involved either impact alone or shaking plus impact then when shaking alone was confessed. As such, better definition of whether skull fractures are present or absent should be helpful in determining whether we are hearing "the truth" or "the whole truth" about these injury events. We have also used 3-D reconstructions in some legal proceedings for which we have testified. We observed that the 3-D reconstructions provided the triers of fact, the judge or lay jury, a much more graphic and understandable representation of the child's injury than the skull films or CT bone windows alone.

This report is limited by its provision of a small nonconsecutive series of exemplary cases which demonstrate how 3-D CT reconstructions can assist abuse evaluations. It does not provide a formal head-to-head comparison of a large consecutive series of possibly abused children to determine the relative benefit of various imaging modalities. The study of Prabhu et al[6] provides such a comparison, but the literature would benefit by its replication.

Because of our experience that missed skull fractures were at least partially responsible for reinjury of children with AHT, our radiology department instituted a policy of performing 3-D reconstructions on all initial cranial CTs in children younger than 3 years. To do so requires a minimum of technologist time and effort and no additional radiation. It makes CT interpretation easier and more accurate for our radiologists. Paraphrasing Prabhu et al, "Another important benefit of 3-D models is that less experienced radiologists" and clinicians, such as emergency physicians, "can recognize fractures and also distinguish them from normal variants."[5] Through our experience, we highly recommend that emergency physicians collaborate with their radiology departments to institute a policy of routine creation of 3-D skull reconstructions for all infants and toddlers for whom trauma is any part of their differential diagnosis.

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