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- Normal craniofacial skeletal anatomy
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- Menu of radiologic tests
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Background:

Epidemiology of craniofacial trauma

• Approximately 50% of the 12 million annual traumatic wounds treated in emergency rooms across the United States involve the head and neck

• Common causes of craniofacial trauma include:
  – Motor vehicle accidents (community setting)
  – Assault (urban setting)
  – Sports injuries and falls
  – Domestic violence

• Among level-1 trauma centers, facial trauma is managed by:
  – Plastic surgeons (40%)
  – Oral and maxillofacial surgeons (36%)
  – Otolaryngologists/head and neck surgeons (23%)
  – General surgery and Oculoplastics (~0.5%)

Singer, Hollander, Quinn Aksoy, Unlu, Sensoz Bagheri et al Holmes
Background:
Why recognition and management of craniofacial trauma is crucial

• The face contains crucial specialized systems needed to see, hear, smell, breathe, eat, and speak

• Vital structures within the head and neck are intimately associated

• Several facial injuries may be life threatening:
  – Hemorrhage
  – Airway obstruction
  – Aspiration

• The psychological impact of facial disfigurement can be devastating
Background:
Clinical exam findings in the recognition of craniofacial trauma

- Facial asymmetry
- Pain upon palpation
- Facial instability
- Cortical step-offs
- Periorbital edema
- Periorbital crepitus
- Infraorbital numbness
- Epistaxis
- Epiphora
- Exophthalmus
- Enophthalmus
- Telecanthus
- Orbital muscle/nerve entrapment
- Many more …
Background:
Limitations of the clinical exam in the recognition of craniofacial trauma

**Clinical evaluation** of the facial skeleton in trauma patients is difficult:

- Facial features are often obscured and distorted by endotracheal and gastric tubes and tapes that hold them in place. Thus, **evaluation of facial instability** is difficult

- Response to painful stimuli is blunted. Thus, **evaluation of localized pain secondary to fractures** is difficult

Rehm, Rhos
Background:
The crucial role of radiologic imaging in the recognition of craniofacial trauma

- Up to **60% of facial fractures may be missed clinically** (lack of step-offs, instability, orbital entrapment, telecanthus, etc) and are later detected by CT

- **Of those 60% of clinically unsuspected facial fractures later detected on CT, approximately 50% require subsequent surgical repair**

- As a result, though **plastic surgeons and maxillofacial surgeons primarily manage craniofacial trauma**, the **radiologist plays a crucial role in diagnosis to guide management**
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Normal craniofacial skeletal anatomy:
The skull consists of cranial and facial bones

http://www.arthursclipart.org/medical/skeletal/skull%20front%20side.gif
Normal craniofacial skeletal anatomy:
Components of both cranial and facial bones form the orbit – colloquially known as the ‘eye socket’

http://www.arthursclipart.org/medical/skeletal/skull%20front%20side.gif
Normal craniofacial skeletal anatomy:
Lateral view of the 22 bones of the skull,
8 cranial bones and 14 facial bones

8 cranial bones:
1 x Frontal
2 x Parietals
1 x Sphenoid
2 x Temporals
1 x Ethmoid
1 x Occipital

14 facial bones
2 x Lacrimals
2 x Inferior Nasal Conchae
1 x Vomer
2 x Nasals
2 x Zygomatics
2 x Palatines
2 x Maxillae
1 x Mandible

http://www.arthursclipart.org/medical/skeletal/skull%20front%20side.gif
Normal craniofacial skeletal anatomy:
Anterior view of the facial bones and orbit

7 orbital bones
- Frontal
- Sphenoid
- Ethmoid
- Palatine
- Lacrimal
- Zygomatic
- Maxillary

14 facial bones
- 2 x Lacrimals
- 2 x Nasals
- 1 x Vomer
- 2 x Inferior Nasal Conchae
- 2 x Maxillae
- 2 x Palatines
- 2 x Zygomatics
- 1 x Mandible

http://www.arthursclipart.org/medical/skeletal/skull%20front%20side.gif
Normal craniofacial skeletal anatomy:
Skeletal anatomy of the orbit

7 orbital bones
- Frontal
- Sphenoid
- Ethmoid
- Palatine
- Lacrimal
- Zygomatic
- Maxillary

Cranial bones

Facial bones


http://www.arthursclipart.org/medical/skeletal/skull%20front%20side.gif
Normal craniofacial skeletal anatomy:
Anatomy of the mandible

- Coronoid process
- Condylar process
- Ramus

Angle, Body, Symphysis
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Shattered Anatomy: Intro to Patient AA

History

• 37M unhelmeted bicycle rider struck by a car, propelled head first through windshield

• Widely opened multiple cranial and facial fractures with visible brain material, otherwise (remarkably) no other no traumatic injury to the chest, abdomen, or pelvis

• Intubation initially difficult secondary to multiple facial fractures

• Unable to immediately assess for clinical signs of orbital entrapment secondary to patient’s waning mental status
Anterior 3D-reformatted CT reconstructions of the face
Normal patient on the left. Our patient AA on the right
Oblique 3D-reformatted CT reconstructions of the face
Normal patient on the left. Our patient AA on the right.
Severely comminuted, complex frontal bone fractures

R. superior lateral orbital rim fracture

L. lateral orbital wall fracture

Bilateral orbital floor fractures

Bilateral LeFort II fractures

Comminuted fractures of the ethmoid and sphenoid sinuses, nasal bone fractures

Anterior 3D-reformatted CT reconstruction of the face
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Menu of radiologic tests:

Traditional facial radiograph series—outdated in the evaluation of facial trauma

- Traditional facial radiographic series include those such as the 'Waters view,' 'Caldwell view,' ‘Towne view’ and submentovertex view

- Such views are **outdated** in evaluation of facial trauma:
  - difficulty of interpretation amongst non-radiologist physicians
  - inability to assess soft tissues in detail
  - advent of CT and 3D CT reformatting

Chen, Ng, Whaites

Menu of radiologic tests:
Facial Multidetector CT – the imaging gold standard

- Facial Multidetector CT without contrast with axial and coronal sections is the gold standard in the evaluation of facial trauma
  - Fast
  - Bone windows may evaluate for fractures
  - Soft tissue windows may simultaneously evaluate for secondary soft tissue swelling (including extra-ocular muscles, nerves, and globe) and hematomas
  - Coronal sections are superior to radiographs in showing orbital floor fractures
  - Subsequent 3D CT reformatting is possible
Menu of radiologic tests:
CT with 3D reformatting – Background

• Contiguous 2D CT slices are obtained via normal CT protocol

• These series of tomographs are analyzed by a 3D software program

• The computer essentially uses one of two rendered techniques to obtain a 3D image:
  1 – Threshold/Surface Rendering
  2 – Volume Rendering

Kung, Fung
Menu of radiologic tests:
CT with 3D reformatting – Surface rendering and volume rendering

- Principle behind threshold/surface rendering is based on the Hounsfield scale (quantitative scale for radiodensity in CT using Hounsfield Units = HU)

- Can select CT attenuation value of +150 HU as threshold, and thus all soft tissues (below +150 HU) excluded in final 3D CT image, and only bone (and other structures with HU > +150) included

- Volume rendering performs a similar algorithm using summation
Menu of radiologic tests:
CT with 3D reformatting – Conceptually simplified

Combining with coronal sections

Applying rendering algorithms using HU thresholds to subtract soft tissues

Axial CT sections obtained from PACS BIDMC; stacked graphic created independently
3D CT Face reconstruction image obtained from GE Vitrea 3D Workstation, MGH
Menu of radiologic tests:
CT with 3D reformatting – useful for the surgeon

- Surgeons generally ‘think in 3D’ vs. radiologists with specialized training in 3D interpretation of 2D imaging

- 3D reformatting may aid in pre-surgical planning

- 3D reformatting may aid in the design of custom facial prosthetics

Reuben, Watt-Smith, Dobson, et al
Alder, Deahl, Matteson
Menu of radiologic tests:
Panorex

- 2D panoramic x-ray (radiograph) of the upper and lower teeth and mandible
- Displays the mandible as a flat structure
- Combined with CT, picks up virtually all fractures of the mandible
- When used alone, often misses parasymphysial fractures of the mandible

Romeo, Pinto, Cappabianca, et al
Menu of radiologic tests:
Panorex – may miss mandibular fractures if used alone

This patient was initially noted to only have 1 left nondisplaced fracture at the junction of the mandibular ramus and condylar process from this Panorex
Menu of radiologic tests:
Panorex – may miss mandibular fractures if used alone

- This patient was initially noted to only have 1 left nondisplaced fracture at the junction of the mandibular ramus and condylar process from this Panorex

Panorex film of the mandible, upper and lower teeth
Menu of radiologic tests:
Panorex – should be used in conjunction with CT for the evaluation of mandibular fractures

- On subsequent CT, however, in addition to known left mandibular fracture, she was found to have 2 additional mandibular fractures: a right condylar process fracture, and a parasymphysial fracture.
Menu of radiologic tests:
Panorex – should be used in conjunction with CT for the evaluation of mandibular fractures

- On re-evaluation of original Panorex, the 2 additional fractures seen on CT became apparent, though still difficult to assess on Panorex alone
The patient subsequently had arch bar placement and wire fixation of her maxillary and mandibular teeth.

Panorex film of the mandible, upper and lower teeth; post arch bar placement and wire fixation of upper and lower teeth.
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Severely comminuted, complex frontal bone fractures

Patient AA revisited:
Frontal bone fractures

Severely comminuted, complex frontal bone fractures

Anterior 3D-reformatted CT reconstruction of the face

GE Vitrea 3D Workstation, MGH
Patient AA revisited:
Frontal bone fractures on CT

Axial CT through the level of the frontal bone; bone window
Patient AA revisited:
Frontal bone fractures on CT, Findings

- Numerous severely comminuted fractures of the frontal bone
- Low attenuation areas of subcutaneous emphysema
- High attenuation foreign objects, likely lead-containing glass fragments (as patient was projected head first through windshield)
Patient AA revisited:
Orbital rim, wall, and floor fractures

**OUR PATIENT, AA**

- **R. superior lateral orbital rim fracture**
- **L. lateral orbital wall fracture**
- **Bilateral orbital floor fractures**

Anterior 3D-reformatted CT reconstruction of the face
Patient AA revisited:
Orbital fractures on CT

Coronal C- CT through the level of the orbits; bone window
Sagittal C- CT through the level of left orbit; bone window

AGFA, MGH
Patient AA revisited
Orbital fractures on CT, Findings

- Non-orbital fracture seen: **Depressed skull fragment of frontal bone** (on soft tissue window seen to cause cerebral edema, necessitating subsequent craniectomies and ventriculostomy)

- Complex **displaced fracture of the right superior lateral orbital rim**

- Non-displaced **fracture of the left lateral orbital wall**

- Bilateral **comminuted orbital floor fractures**

- **Depressed orbital floor fracture on the right**
Patient AA revisited:
Orbital injury on CT, soft tissue window

Coronal CT through the level of the orbits; soft tissue window

AGFA, MGH
Patient AA revisited:
Orbital injury on CT, soft tissue window findings

- Extra-ocular muscles within orbit
- Downward herniation of periorbital fat (HU: –60) into right maxillary sinus
- Blood in bilateral maxillary sinuses
- No evidence of optic nerve or extraocular muscle entrapment seen on subsequent clinic exam (PERRL; negative forced duction test)
Patient AA revisited:
Bilateral LeFort II fractures

OUR PATIENT, AA

Anterior 3D-reformatted CT reconstruction of the face

Bilateral LeFort II fractures

GE Vitrea 3D Workstation, MGH
Patient AA revisited:
Bilateral LeFort II fractures on CT

Axial CT through the level of sphenoid; bone window
Coronal CT through the level of the maxilla; bone window
Patient AA revisited:
Bilateral LeFort II fractures on CT,
Findings

- Bilateral fractures of the pterygoid processes of the sphenoid (defines all LeFort maxillary fractures)

- Bilateral medial orbital wall fractures resulting in pyramidal pattern of the LeFort II fracture
Patient AA revisited:
Comminuted fractures of the ethmoid and sphenoid sinuses, nasal bone fractures

Comminuted fractures of the ethmoid and sphenoid sinuses, nasal bone fractures

Anterior 3D-reformatted CT reconstruction of the face
Patient AA revisited:
Comminuted fractures of the ethmoid and sphenoid sinuses, nasal bone fractures on CT
Patient AA revisited:
Comminuted fractures of the **ethmoid** and **sphenoid** sinuses, **nasal bone fractures** on CT, Findings (with **blood** in both sinuses)

Axial CT through the level of the ethmoid and sphenoid sinuses
Bone window

Axial CT through the level of the nasal bones
Bone window

AGFA, MGH
Patient AA revisited:
Summary of all fractures

**OUR PATIENT, AA**

- Severely comminuted, complex frontal bone fractures
  - R. superior lateral orbital rim fracture
  - L. lateral orbital wall fracture
  - Bilateral orbital floor fractures
  - Bilateral LeFort II fractures
  - Comminuted fractures of the ethmoid and sphenoid sinuses, nasal bone fractures

Anterior 3D-reformatted CT reconstruction of the face

GE Vitrea 3D Workstation, MGH
Patient AA revisited:
Follow-up

Our Patient, AA Post-op

- Due to elevated intracranial pressure, underwent bifrontal craniectomies
- Left ventriculostomy tube was placed
- **ORIF** of frontal sinus fracture

Anterior 3D-reformatted CT reconstruction of the face post bifrontal craniectomies with ventriculostomy tube placement, and ORIF of comminuted frontal sinus fractures

GE Vitrea 3D Workstation, MGH
Patient AA revisited:
Post craniectomies and ventriculostomy tube imaging

Oblique 3D-reformatted CT reconstruction of the face post bifrontal craniectomies with ventriculostomy tube placement

Sagittal C- CT Head post bifrontal craniectomies with ventriculostomy tube placement

GE Vitrea 3D Workstation, MGH
AGFA, MGH
Patient AA revisited:
List of subsequent craniofacial reconstructive procedures

• Bilateral arch bar placement with intermaxillary fixation

• ORIF of right zygomaticofrontal suture

• ORIF of right orbital floor fracture with reconstruction of the floor with alloplastic implant

• ORIF of bilateral LeFort II fractures

• Closed reduction of the nasal fractures
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Conclusions

- Craniofacial trauma can be devastating if not acutely recognized and managed.
- The recognition of craniofacial trauma depends heavily on radiologic imaging since the clinical exam is unreliable (60% of facial fractures are missed clinically).
- Facial CT is the gold standard in the evaluation of facial trauma: facial radiographs are outdated, except for Panorex which still has utility when used in conjunction with CT in the evaluation of mandibular fractures.
- 3D CT reconstructions provide useful information in surgical planning.
Acknowledgments

• Gillian Lieberman, MD
• Yoon S. Chun, MD
• Hillary Kelly, MD
• Gregory Czucziman, MD
• David Li, MD
• Maria Levantakis
• Linda Burke
References

8– Chen TW, Ng SY, Whaites EJ. Interpretation of skull radiographs for facial fractures by medical staff working in UK emergency departments: a pilot study. Dentomaxillofac Radiol. 2003;32(3):166–72