BC Cancer Agency
CARE + RESEARCH
An agency of the Provincial Health Services Authority

Practical Medical Physics:

Head & Neck and Lung Contouring

AAPM 2012

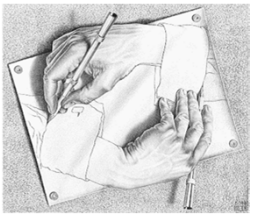
Charlotte, North Carolina

Jonn Wu, BMSc MD FRCPC
Radiation Oncologist, Vancouver Cancer Centre, BCCA
Clinical Assistant Professor, UBC

July 30th, 2012

Objectives

Review Selection of Normal Organs
- Salivary Glands
  - Parotid
  - Submandibular
- Brachial Plexus
- Esophagus
- Trachea, Bronchial Tree

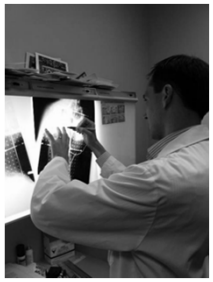


Target Audience:
- Physicists
- Dosimetrists
- Radiation Therapists

BC Cancer Agency
CARE + RESEARCH
An agency of the Provincial Health Services Authority

Outline

Why do we have to Contour?
Which Organs are Important?
How *I* contour?
3 Important Organ Systems
- Xerostomia: Salivary Glands
  - Parotid
  - Submandibular
- Brachial Plexus
- Esophagus
- Trachea, Bronchial Tree



BC Cancer Agency
CARE + RESEARCH
An agency of the Provincial Health Services Authority

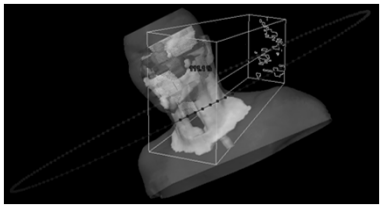
Outline (cont)

For Each Organ System
- Anatomy
- Literature
- Examples

BC Cancer Agency
CARE + RESEARCH

Why do we have to contour?

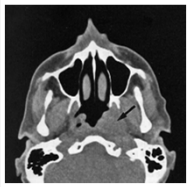
- Target delineation
- Organ definition

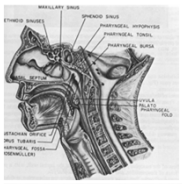


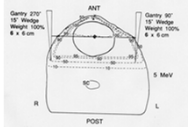
2D → 3D → IMRT
(your fault)

BC Cancer Agency
CARE + RESEARCH

2D Planning

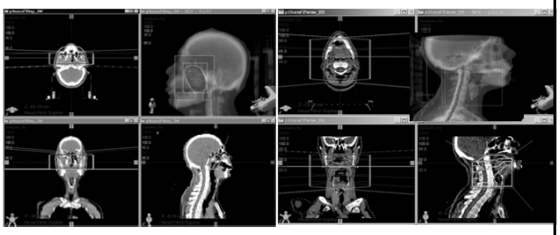






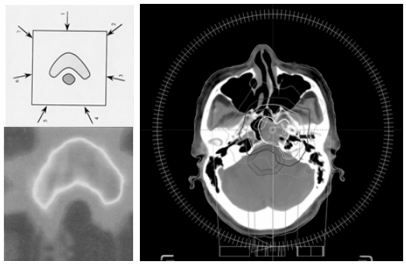
BC Cancer Agency
CARE + RESEARCH

3DCRT



BC Cancer Agency
CARE + RESEARCH

IMRT

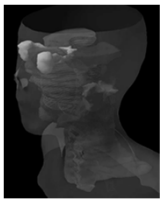


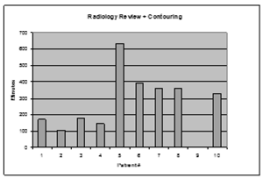
BC Cancer Agency
CARE + RESEARCH

Mark Phillips (UW, 1997)

IMRT & Contours

- Inverse Planning
- Objective Cost Function
- Computers are Binary





BC Cancer Agency
CARE + RESEARCH

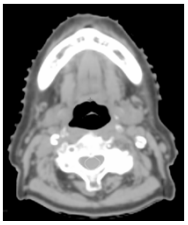
Why take a contouring course?

- IMRT and 3D = standard practice
  - Both techniques require (accurate) contours
  - Clinical trials require dose constraints
- Consistency (precision)
  - Who:
    - Intra- vs inter-contourer
    - Intra- vs inter-institutional
  - Why:
    - Good practice
    - Dose constraints
    - Dosimetric repositories

BC Cancer Agency
CARE + RESEARCH

Why take a contouring course?

- No formal training
- Few reproducible guidelines
- Everyone assumes consistent contouring
  - NCIC HN6, RTOG 0920, 0615, 0225
  - Spinal Cord:
    - Intra-observer: avg 0.1 cm, max 0.7 cm
    - Inter-observer: avg 0.2 cm, max 0.9 cm
- Long term sequelae



BC Cancer Agency
CARE + RESEARCH

Geets RO 2005

Which organs are important

Brain (temporal lobe)
Globe, retina
Lens
Optic nerve, Optic chiasm
Pituitary gland
Brainstem, Spinal cord
Inner ear
TMJ
Mandible
Larynx
Esophagus
Oral cavity
Thyroid
Vasculature, Great Vessels, Heart
Trachea, Proximal Bronchial Tree
Lung
Ribs
Skin

Dysphagia- Pharyngeal Constrictors

Xerostomia - Salivary Glands

Plexopathy - Brachial plexus

Dysphagia – Esophagus

Fistula – Trachea, Bronchial Tree

BC Cancer Agency
CARE + RESEARCH

For Each Organ System

- Anatomy
- Literature
- Examples

(No Time For)
- Targets (GTV)
- ICRU (xTVs, PRV)
- Contour editing (surface cropping, overlapping)
- Autosegmentation
- Imaging modalities
- Intra-treatment changes
- Dose volume constraints

BC Cancer Agency
CARE + RESEARCH

How *I* Contour

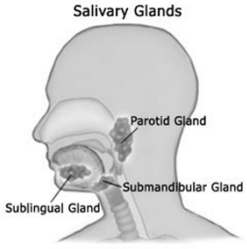
- Standard CT technique
  - 2.5mm slices, 2.5mm spacing
  - Matrix size 512 x 512
  - IV Contrast
- HU Settings
  - Window 400, Level 50
- Maximize screen real estate
- ***Scrolling***
- Software tools: above/below
- Tablet/Pen
- Consultation: RO, DI

Holistic Contouring
Digital & Physical Optimization

BC Cancer Agency
CARE + RESEARCH

Xerostomia: Salivary Glands

- Anatomy
- Literature
- Examples



BC Cancer Agency
CARE + RESEARCH

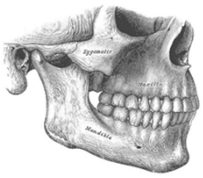
Salivary Glands: Anatomy

- Major Salivary Glands
  1. Parotid
  2. Submandibular
  3. Sublingual
- Secrete saliva
  - Speech, taste, swallowing
  - Digestive enzymes
  - Prevent inflammation and dental caries
- Saliva
  - 0.5 L secreted per day
    - **Resting**: 0.3 mL/min
      - Parotid = 20%
      - **Submandibular = 65%**
      - **Sublingual, Minor = 15%**
    - Stimulated: 1.5–2 mL/min
      - **Parotid** = 50%

BC Cancer Agency
CARE + RESEARCH

Salivary Glands: Parotid

- paired, 25-30 g, accessory gland: 20%
- potential borders:
  - superior: zygomatic arch
  - inferior: hyoid bone
  - anterior: anterior ramus mandibular arch
  - posterior: mastoid process
  - medial: carotid sheath or masseter muscle
  - lateral: skin

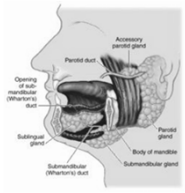


- Structures within Parotid
  - External carotid artery, Retromandibular vein
  - Facial nerve
- Parotid Duct:
  - 5 cm long, 3 mm wide
  - Crosses masseter, right angle, buccal fat pad/buccinator, runs obliquely forwards, opens @ second upper molar

BC Cancer Agency
CARE + RESEARCH

Salivary Glands: Submandibular

- 10-20 g, size of walnut
- Borders:
  - Superior: medial surface of mandible, lingual N
  - Inferior: soft tissues of neck, hypoglossal N
  - Medial/Anterior: floor of mouth (mylohyoid, hypoglossus mm)
  - Posterior: submandibular LN, carotid sheath
  - Lateral: skin



BC Cancer Agency
CARE + RESEARCH

Salivary Glands: Literature

Organ at risk	Anatomic boundaries					
	Cranial	Caudal	Anterior	Posterior	Lateral	Medial
Parotid gland	External auditory canal, mastoid process	Post. part submandibular space	Masseter m., post. border mandibular bone, medial and lateral pterygoid m.	Ant. belly sternocleidomastoid m., lat. side post. belly of the digastric m. (posterior-medial)	Subcutaneous fat, platysma	Post. belly of the digastric m., styloid process, parapharyngeal space
Submandibular gland	Medial pterygoid m., mylohyoid m.	Fatty tissue	Lat. surface mylohyoid m., hyoglossus m.	Parapharyngeal space, sternocleidomastoid m.	Med. surface medial pterygoid m., med. surface mandibular bone, platysma	Lat. surface mylohyoid m., hyoglossus m., superior and middle pharyngeal constrictor m., anterior

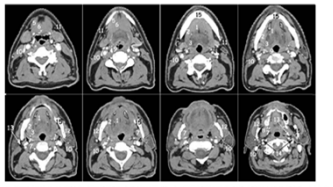


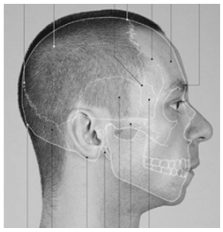
Fig. 2. Major salivary glands: the parotid glands are depicted in brown (left) and green (right), the submandibular glands are depicted in blue (the left one is brighter than the right one) and the sublingual glands are coloured dark blue (anterior part and cardo). (1) Genioglossus m., (2) mylohyoid m., (3) hyoglossus m., (4) posterior belly digastric m., (5) anterior belly digastric m., (6) geniohyoid m., (7) medial pterygoid m., (8) lateral pterygoid m., (9) pharyngeal constrictor m., (10) sternocleidomastoid m., (11) platysma, (12) masseter m., (13) parapharyngeal space, (14) styloid process, (15) mandibular bone.

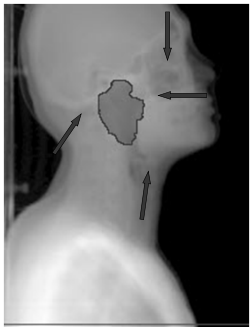
BC Cancer Agency
CARE + RESEARCH
An agency of the Provincial Health Services Authority

Van de Water et al, RO, 2009

Parotid Glands: Examples

- superior: zygomatic arch
- inferior: hyoid bone
- anterior: anterior ramus mandibular arch
- posterior: mastoid process
- medial: carotid sheath or masseter muscle
- lateral: skin



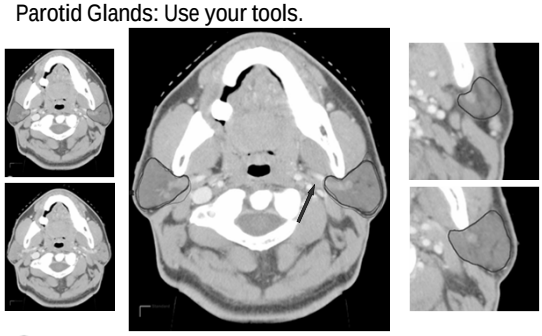


BC Cancer Agency
CARE + RESEARCH
An agency of the Provincial Health Services Authority

Parotid Glands: Examples

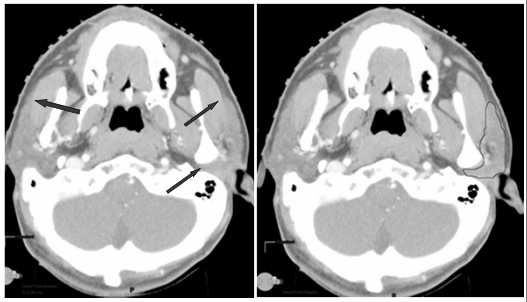
BC Cancer Agency
CARE + RESEARCH
An agency of the Provincial Health Services Authority

Parotid Glands: Use your tools.



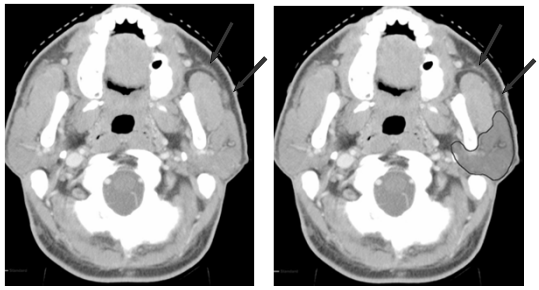
BC Cancer Agency
CARE + RESEARCH

Parotid Glands: Examples



BC Cancer Agency
CARE + RESEARCH

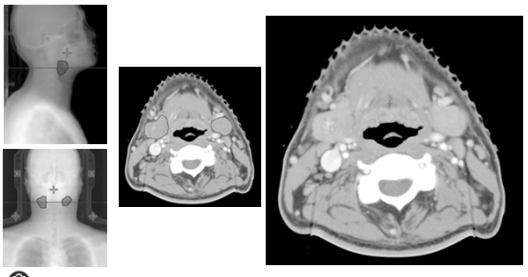
Parotid Glands: Examples



BC Cancer Agency
CARE + RESEARCH

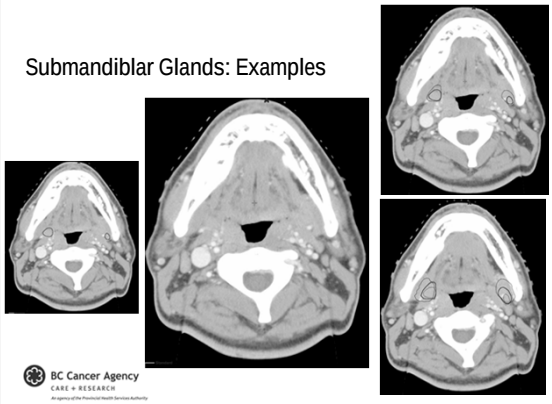
Submandibular Glands

- Superior: medial surface of mandible, lingual N
- Inferior: soft tissues of neck, hypoglossal N
- Medial/Anterior: floor of mouth (mylohyoid, hypoglossus mm)
- Posterior: submandibular LN, carotid sheath
- Lateral: skin



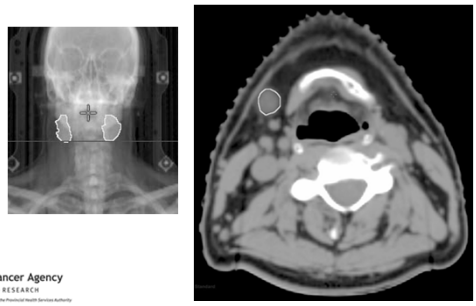
BC Cancer Agency
CARE + RESEARCH

Submandiblar Glands: Examples



BC Cancer Agency
CARE + RESEARCH

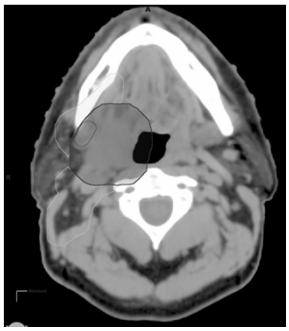
Submandibular Glands: Inferior



BC Cancer Agency
CARE + RESEARCH

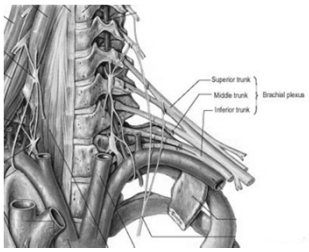
Salivary Glands: Summary

- Parotid most variable
- Submandibular: inferior is easiest
- Know potential limits
- Scroll
- Sup/Inf tool



BC Cancer Agency
CARE + RESEARCH

Brachial Plexus



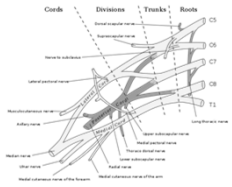
- Anatomy
- Literature
- Examples

BC Cancer Agency
CARE + RESEARCH

Brachial Plexus: Anatomy

- Cutaneous and muscular innervation "most" of upper limb
  - Two exceptions:
    - trapezius muscle (spinal accessory nerve [CN XI])
    - area of skin near axilla (intercostobrachial nerve)
- The five **roots** merge to form three **trunks**:
  - Super: C5, C6
  - Middle: C7
  - Inferior: **C8**, T1

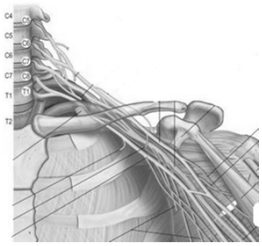
Hard To See!



BC Cancer Agency
CARE + RESEARCH

Brachial Plexus: 5 Roots → 3 Trunks

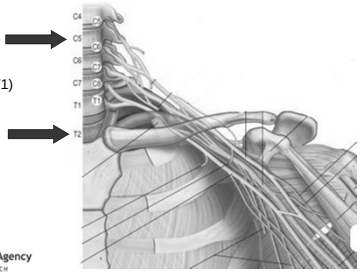
**** Note ****
- Seven cervical vertebrae (C1-C7)
- Eight cervical nerves (C1-C8)
  - C1-C7: emerge *above Cx*
  - C8: emerges *below* C7
  - T1 etc emerge *below T1*



BC Cancer Agency
CARE + RESEARCH

Brachial Plexus: Landmarks

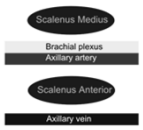
C5, T2 (or T1)

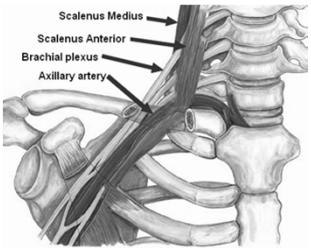


BC Cancer Agency
CARE + RESEARCH

Brachial Plexus: Landmarks

Brachial Plexus travels between:
- **Scalenus Anterior**
- **Scalenus Medius**





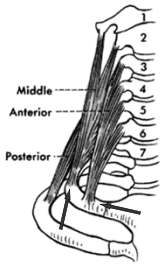
BC Cancer Agency
CARE + RESEARCH

Dr. Monty Martin, BCCA (Chief, Neuroradiology)

Brachial Plexus: Ant/Med Scalenus

Anterior Scalenus:
- aka scalenus anterior, scalenus anticus
- transverse processes of C3-C6 to first rib
  - anterior to medial scalenus

Medial Scalenus:
- largest and longest of the three scalene muscles
- posterior tubercles of transverse processes C2-C7 to first rib

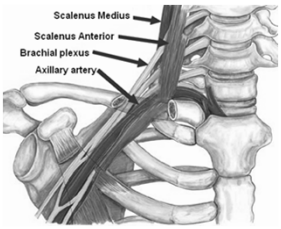


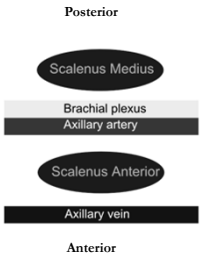
The scalene muscles.

BC Cancer Agency
CARE + RESEARCH

Brachial Plexus: Axilla

- Behind **Axillary Artery**



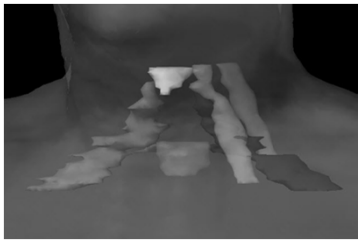


BC Cancer Agency
CARE + RESEARCH

Brachial Plexus: Landmarks

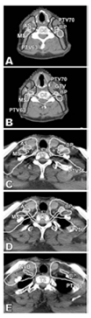
- C5
- T1 or T2
- Anterior scalenus
- Medial scalenus

Axilla:
- Axillary artery

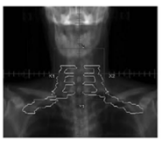


BC Cancer Agency
CARE + RESEARCH

Brachial Plexus: Literature



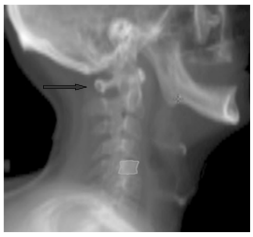
1. Identify and contour C5, T1, and T2.
2. Identify and contour the subclavian and axillary neurovascular bundle.
3. Identify and contour anterior and middle scalene muscles from C5 to insertion onto the first rib.
4. To contour the brachial plexus OAR use a 5-mm diameter paint tool.
5. Start at the neural foramina from C5 to T1; this should extend from the lateral aspect of the spinal canal to the small space between the anterior and middle scalene muscles.
6. For CT slices, where no neural foramen is present, contour only the space between the anterior and middle scalene muscles.
7. Continue to contour the space between the anterior and middle scalene muscles; eventually the middle scalene will end in the region of the subclavian neurovascular bundle.
8. Contour the brachial plexus as the posterior aspect of the neurovascular bundle inferiorly and laterally to one to two CT slices below the clavicular head.
9. The first and second ribs serve as the medial limit of the OAR contour.

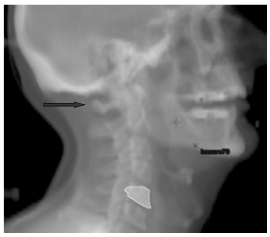


BC Cancer Agency
CARE + RESEARCH

Hall et al, IJROBP, 2008

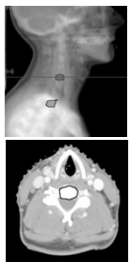
Brachial Plexus: Examples – C5

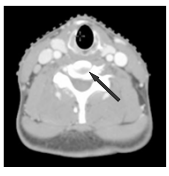


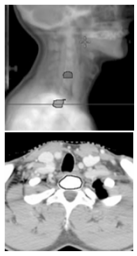


BC Cancer Agency
CARE + RESEARCH

Brachial Plexus: Examples – T1





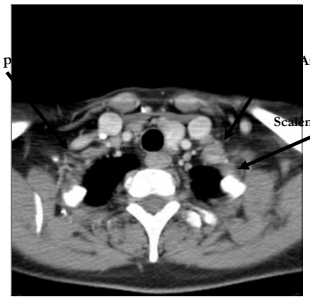


BC Cancer Agency
CARE + RESEARCH

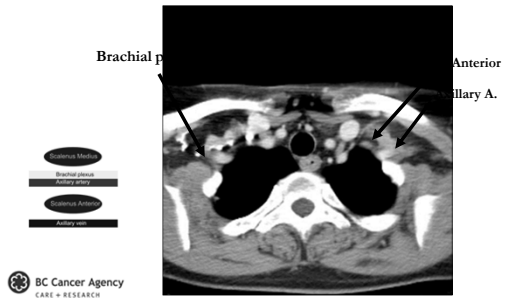
Brachial Plexus: Scalenus mm

Brachial Plexus: Scalenus mm

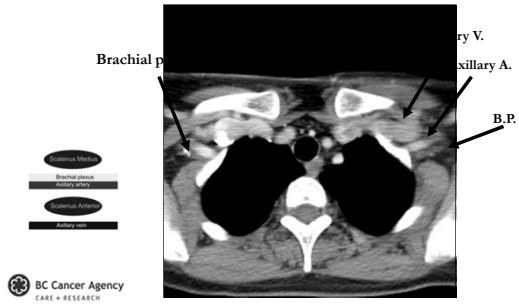
Brachial Plexus: Scalenus mm



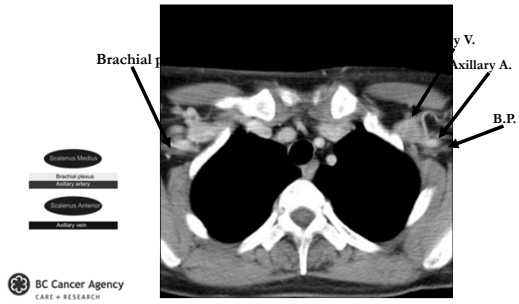
Brachial Plexus: Scalenus mm



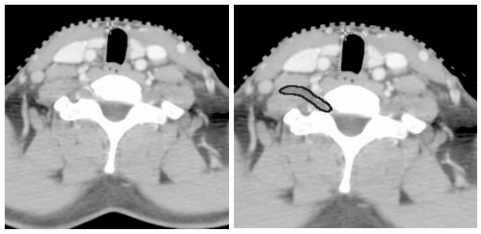
Brachial Plexus: Scalenus mm



Brachial Plexus: Scalenus mm

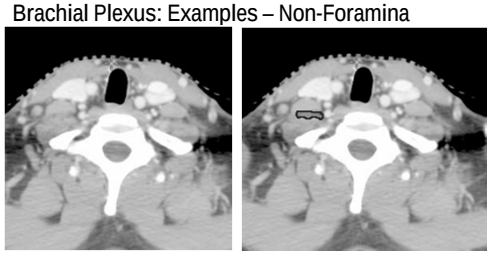


Brachial Plexus: Examples – Foramina



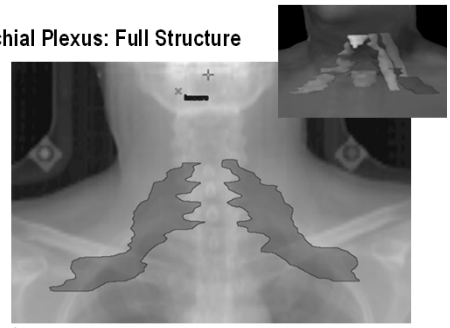
BC Cancer Agency
CARE + RESEARCH

Brachial Plexus: Examples – Non-Foramina



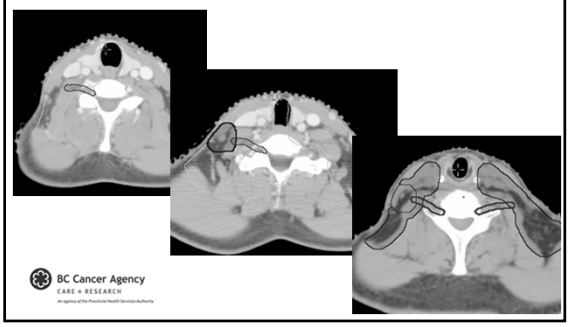
BC Cancer Agency
CARE + RESEARCH

Brachial Plexus: Full Structure



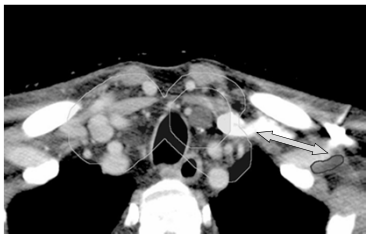
BC Cancer Agency
CARE + RESEARCH

Brachial Plexus: Examples



BC Cancer Agency
CARE + RESEARCH

Brachial Plexus: Axilla



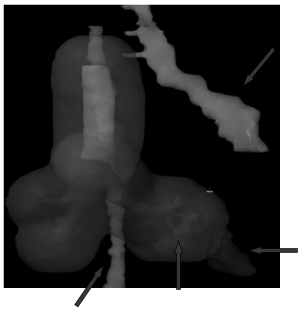
BC Cancer Agency
CARE + RESEARCH

Brachial Plexus: Comments

- Brachial Plexopathy = rare
- Adjacent GTV/LN
- Not contoured off-study @ BCCA
- Reproducible contours possible
- Axilla – Lung SBRT
- Further research
  - Dosimetric Repository

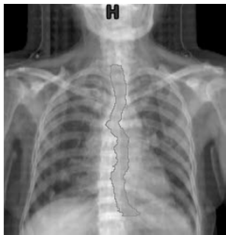
BC Cancer Agency
CARE + RESEARCH

Lung – Esophagus, Trachea



BC Cancer Agency
CARE + RESEARCH

Esophagus

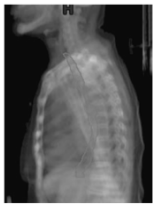


- Anatomy
- Literature
- Examples

BC Cancer Agency
CARE + RESEARCH

Esophagus - Anatomy

- hollow, thin-walled, muscular tube
- peristalsis, from pharynx to the stomach
- posterior mediastinum
  - BEHIND trachea
- average = 25 cm long
- layers
  - mucosa: muscularis (smooth muscle)
  - submucosa: mucous secreting glands
  - muscularis externa (muscularis propria)
  - adventitia



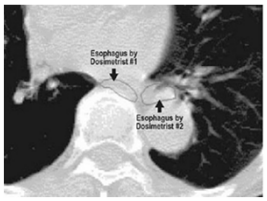
BC Cancer Agency
CARE + RESEARCH

Esophagus - Literature

- Kong et al
  - Cricoid cartilage to GE Junction
  - BCCA: 10 cm above/below PTV
  - Avoid oral contrast
  - Include all 3 layers
  - Mediastinal windows

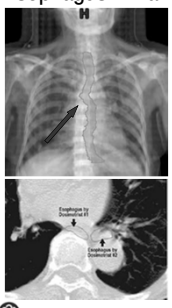
CLINICAL INVESTIGATION

CONSIDERATION OF DOSE-LIMITS FOR ORGANS AT RISK OF THORACIC RADIOTHERAPY: ATLAS FOR LUNG, PROXIMAL BRONCHIAL TREE, ESOPHAGUS, SPINAL CORD, RIBS, AND BRACHIAL PLEXUS



BC Cancer Agency
CARE + RESEARCH

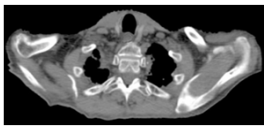
Esophagus - Example



- Main Problems:
  - Kinks
  - Which tissue = esophagus?
- Key Hints:
  - Start with obvious slice
  - SCROLL
  - Software Tool: Above/Below

BC Cancer Agency
CARE + RESEARCH

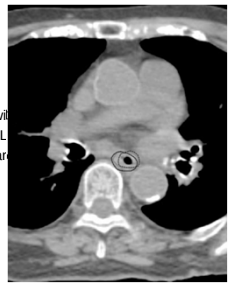
Esophagus - Example



- Key Hints:
  - Start with obvious slice
    - BEHIND trachea
    - Posterior mediastinum
  - SCROLL
  - Software Tool: Above/Below

BC Cancer Agency
CARE + RESEARCH

Esophagus – Example



- Key Hints:
  - Start wi
  - SCROL
  - Softwar

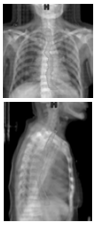
BC Cancer Agency
CARE + RESEARCH

Esophagus - Example

- Key Hints:
  - Start with obvious slice
  - SCROLL
  - Software Tool: Above/Below

BC Cancer Agency
CARE + RESEARCH

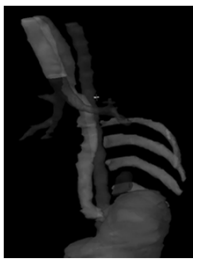
Esophagus - Summary



- Key Hints:
  - Start with obvious slice
    - BEHIND trachea
    - Posterior mediastinum
  - SCROLL
  - Software Tool: Above/Below

BC Cancer Agency
CARE + RESEARCH

Trachea, Bronchial Tree

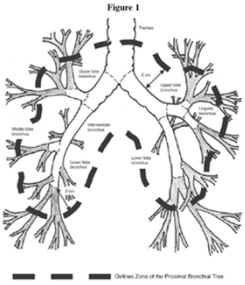


- Anatomy
- Literature
- Examples

BC Cancer Agency
CARE + RESEARCH

Trachea, Bronchial Tree - Anatomy

- connects larynx to lungs
- pseudostratified ciliated columnar epithelium
  - goblet cells produce mucus
- inner diameter 2.5 cm
  - Length 10-16 cm
- ends at carina
  - bifurcates into the primary bronchi
- incomplete cartilaginous rings
- esophagus posterior to trachea

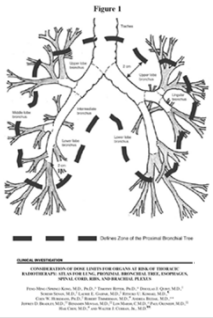


BC Cancer Agency
CARE + RESEARCH

Trachea, Bronchial Tree - Literature

(Kong et al)
- Importance of proximal bronchial tree (PBT)
- Mucosa, submucosa, cartilage rings, airway channels
- PBT
  - Distal 2cm of trachea
  - Carina
  - R/L mainstem bronchi
  - R/L upper lobe bronchi
  - Intermedius bronchus
  - RML bronchus
  - Lingular bronchus
  - R/L lower lobe bronchi

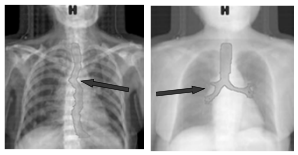
- BCCA: 10 cm above PTV or 5 cm above carina



BC Cancer Agency
CARE + RESEARCH

Trachea, Bronchial Tree - Example

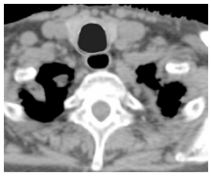
- Key Hints:
  - Start with obvious slice
    - IN FRONT esophagus
  - SCROLL
  - Software Tool: Above/Below



BC Cancer Agency
CARE + RESEARCH

Trachea, Bronchial Tree - Example

- Key Hints:
  - **Start with obvious slice**
    - IN FRONT esophagus
  - SCROLL
  - Software Tool: Above/Below



BC Cancer Agency
CARE + RESEARCH

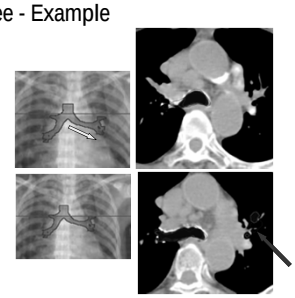
Trachea, Bronchial Tree - Example

- Key Hints:
  - Start with obvious slice
    - IN FRONT esophagus
  - SCROLL
  - Software Tool: Above/Below
  - **Find carina**

BC Cancer Agency
CARE + RESEARCH

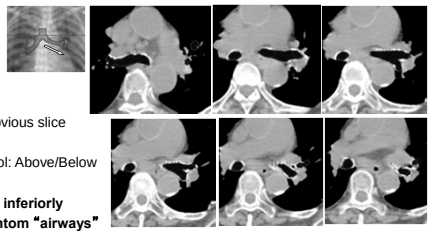
Trachea, Bronchial Tree - Example

- Key Hints:
  - Start with obvious slice
    - IN FRONT esophagus
  - SCROLL
  - Software Tool: Above/Below
  - Find carina
  - **Keep going inferiorly**
  - **Ignore phantom "airways"**



BC Cancer Agency
CARE + RESEARCH

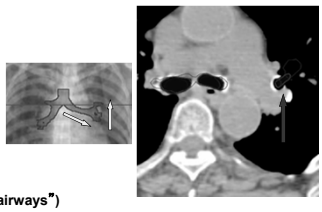
Trachea, Bronchial Tree - Example



- Key Hints:
  - Start with obvious slice
  - SCROLL
  - Software Tool: Above/Below
  - Find carina
  - **Keep going inferiorly**
  - **Ignore phantom "airways"**

BC Cancer Agency
CARE + RESEARCH

Trachea, Bronchial Tree - Example

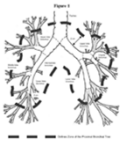


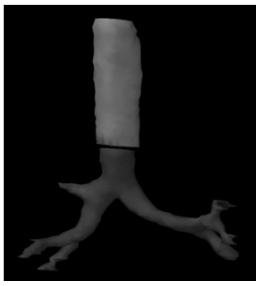
- Key Hints:
  - Start with obvious slice
  - SCROLL
  - Software Tool: Above/Below
  - Find carina
  - Keep going inferiorly
  - Ignore phantom "airways"
  - **Go backwards (phantom "airways")**

BC Cancer Agency
CARE + RESEARCH

Trachea, Bronchial Tree - Summary

- Key Hints:
  - Start with obvious slice
  - SCROLL
  - Software Tool: Above/Below
  - Find carina
  - Keep going inferiorly
  - Ignore phantom "airways"
  - Go backwards (phantom "airways")

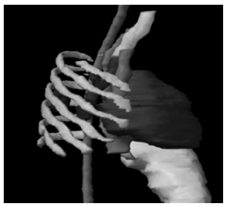




BC Cancer Agency
CARE + RESEARCH

H&N / Lung Contouring: Summary

- Parotid Gland: variable in shape
- Submandibular Gland: difficult = superior end
- Brachial Plexus: requires further study
- Esophagus, Trachea, Bronchial Tree:
  - Start with obvious slice
  - SCROLL
  - Software Tool: Above/Below
  - Find carina
  - Keep going inferiorly
  - Ignore phantom "airways"
  - Go backwards (phantom "airways")
- Window level, maximize screen real estate
- Tablet/Pen
- Consultation: RO, DI



BC Cancer Agency
CARE + RESEARCH

Acknowledgements

Dr. John Hay (Radiation Oncologist)
Drs. M. Martin, C. Mar, Y. Arzoumanian (Radiologists)

jonnwu@bccancer.bc.ca

BC Cancer Agency
CARE + RESEARCH